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ABSTRACT

This project report establishes a framework for viewing educational needs and change from the context of social technological change, synthesizes the research and policy implications of such a perspective, provides guidance on preparing and dealing with the new educational issues which will result from changing technology during this decade, and demonstrates the necessity of integrating technological concerns into the mainstream of general educational thought and practice. Preliminary sections describe the nature of the technology events during this decade, discuss the implications of the environmental technological events for changing the nature of educational needs and the types of educational services demanded by the public, examine the impact of technology events on the evolution of technological opportunity, and discuss the implications for developing new forms of delivery systems. Impediments to increased use of technology in education are examined, and a theory of the consequences of inadequate public school response to technological needs is presented. The final sections discuss federal policy and research issues and present a summary. A six-page bibliography and a cost estimate for a computer-rich classroom in 1985 are included. (Author/LMM)

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TECHNOLOGICAL CHANGE: POLICY IMPLICATIONS FOR FUNDING AND DELIVERING EDUCATIONAL SERVICES IN THE 80's

by

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INTRODUCTION

Issues related to the use and impact of technology in education have been largely the domain of a small group of people who have worked in areas such as computer assisted instruction (CAI) and artificial intelligence.[1] The work of these technologists has been essentially peripheral to the major traditions of educational thought and practice. Technology issues have also been largely ignored by the scholarly traditions of disciplines such as political science, sociology and finance which provided much of the intellectual basis for educational policy during the past two decades.

Technologists have occasionally exerted some influence on educational practice (as they did with disastrous consequences in the late 60's), and have participated in policy deliberations about education (as occurred during the 1979-80 hearings by George Brown's House Subcommittee on Science, Research and Technology). Aside from the occasional instances just cited, however, research about the development and impact of technology in schools and society has been essentially segregated from the intellectual traditions of education and much of the social sciences.[2] Educators and social scientists consider themselves lay people when it comes to technology. Information about technology is published in technical journals which are not read by educational practitioners or scholars. One does not find articles about computers in the Harvard Educational Review or the American Political Science Review. Recent assessments of the impact of changing technology in education, such as the joint NSF-DOE (1980) study, Nilles et al. (1980) and Walling, Thomas & Larson (1979), have been ignored by educators and educational publications, even as the Office of Technology Assessment begins a two year study on the subject. There have been virtually no articles in practitioner oriented school administration journals about computers despite the fact that most school administrators rely extensively on their use. Policy groups which assess the social impact of technology tend to be housed in business or engineering schools, as opposed to colleges of liberal arts and sciences, or schools of public administration. Departments of technology in colleges of education still tend to focus on training teachers how to operate old (in a technology sense) mechanical devices such as movie projectors.

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[1] The term technology as used throughout this paper, unless otherwise specified, will refer to electronic technology. This includes computers, or telecommunication devices, robots and other equipment and services which depend primarily on computers for their operation.

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[2] Social scientists of course use the computer to analyze their data, but seldom collect data about how the computer changes social systems. The work of Kent Kramer's group at Irvine is a notable exception.

The bifurcation that has occurred between those who study the implications of technological development and those who are concerned with the generation of social science theory is largely a result of different backgrounds, language systems and interests. It is rare that these cultural differences are bridged, although it does occasionally happen. A notable recent example of successful integration of these cultures is Seymour Papert's (1980) book Mindstorms. Mindstorms talks about technology from the perspectives of learning theory and anthropology, and focuses on the world of children instead of engineering issues.

The lack of integration between technology and educational policy analysis was of little consequence under the conditions that prevailed during the 60's and 70's. While a number of significant scientific breakthroughs occurred in physics and biology labs, the technologies that were relevant to everyday life underwent slow evolutionary change, and contained no real surprises or new opportunities for education. (Sesame Street was a notable exception.) Cars got better but everyone still drove to work at pretty much the same speed. The period of the 80's, however, appears to be one of those rare times when revolutionary new technologies emerge which present opportunities, and compelling economic incentives, to change the way in which work is performed. Not since the beginning of the industrial revolution, when the compelling economics of the factory overwhelmed the political arrangements that had reinforced the preeminence of the craft guilds, and the urban lifestyle replaced the rural one, has there been available such powerful new technological alternatives and fiscal incentives for modifying the routines of everyday life. Under such conditions, failure to integrate technological issues into formulations of educational policy and social science theory can result in misdirected policy initiatives that are based on precedents that no longer apply, and social science theories that ignore the real-time structural changes that are occurring in society. Social scientists rarely have the opportunity to study economic revolutions in real-time and it would be unfortunate if such an opportunty were lost because of existing scholarly traditions.

There are three main objectives for this paper. The first is to establish a framework for viewing educational needs and change primarily from the context of social technological change, and to synthesize the research and policy implications of such a perspective. The second objective is to provide useful guidance to the policy makers and educators on how to prepare for, and deal with, the new set of educational issues and possibilities that will be brought on by changing technology during this decade. The third objective of the paper is to bring technological concerns into the mainstream of general educational thought and practice by demonstrating the intellectual importance, and pragmatic necessity, of such integration. Indeed, it will be suggested that adapting to new technological realities is the most important policy issue facing public education during this decade if it is to avoid emerging into the 1990's as a vestige of an economic order that is being supplanted, and an homage to political relationships that no longer exist.

If this paper is to provide useful insights on how to adapt to changing circumstances it needs to provide specific projections about the future and its consequences. Simply talking about possible future alternatives, while protecting the author against the possibility of being wrong, does not seem appropriate for the criterion of "usefulness". The need for at least some degree of precision in the estimates dictated the methodological approach that was selected.

1. Description of the methodology- A review of existing policy work in the area of educational technology

revealed three problems. First of all, much of the work (e.g. Kincaid, McEachron & McKinney, 1974; Levine, 1980) focuses on the feasibility of using technology in education at only a single point in time--usually the present. To the extent that it takes time for policy interventions to impact the educational system, a single point in time analysis is inadequate under conditions of evolving technology. Another limitation of existing methodology is the tendency to make generalizations about the role and use of technology based on a single factor while ignoring potentially countervailing effects. The most common factors analyzed are whether technology will improve learning effectiveness, or whether educators will willingly adopt technology. The latter factor points to the final limitation of existing methodology; the tendency to treat the use of technology as an internally initiated innovation opportunity. Such studies must inevitably conclude on the basis of precedence that schools will not adopt technology. Such a finding, however, is virtually tautological since large institutions seldom voluntarily innovate in the absence of strong external pressures for change.

In order to avoid these problems a methodology is required which; a) takes a longitudinal perspective, b) examines the interactive effects of a variety of key factors, and c) views technological adoption from the perspective of the nature of the pressures being generated in a given organization's environment. With respect to the latter issue, there appear to be two kinds of environmental or societal factors. The first are general factors such as the overall state of the economy in the world and the U.S. There are also specific environmental factors that influence an organization's adoption decision such as the extent to which the given technology is adopted by competitors and clients. Developing alternative scenarios for each type of environmental factor would have resulted in too many scenarios, and too tenuous a link to educational policy. As a result, it was decided to use a single most likely scenario for the general economic factors; that of slow to moderate growth of the economy throughout the decade with no cataclysmic events such as a world war, a major energy shortage, or a major reduction in world trade resulting from economic protectionism.

Adopting a high probability perspective for the general environmental conditions has the added advantage of also eliminating the need for multiple scenarios of the specific environmental factors. That is, under conditions of relatively stable, even slow, growth, it appears that societal utilization of technology will follow a "relatively" predictable series of phases (which will be described in Part I) that are driven largely by economic factors. As a result, it was decided to substitute the concept of technology events for the use of multiple scenarios. A "technology event" is defined as a particular evolutionary phase in societal utilization of technology.

The basic methodology of this study is to describe time frames for technological events (TE) that can be expected to impact the external environment of schools in specific ways during this decade. Consequences of each TE will be derived (where possible) for each of the following variables:

a) Educational needs (EN)
b) Educational demands (ED)
c) Technological opportunity (TO) for alternative forms of educational delivery systems and political dynamics.

This relationship can be expressed mathematically as:

$$(1)\ TE_i \dashrightarrow EN_i,\ ED_i,\ TO_i$$

The projected impacts of each TE will be explored to determine their policy implications for education. Even if the predicted time spans for TE's turn out to be somewhat inaccurate, the concept is still useful since it provides a benchmark against which to adjust the time frames for the policy concerns generated by the functional consequences of equation (1).

While the variables in equation (1) can be viewed as linked by elements of economic determinism, and thereby subject to forces that are at least partly rational (hence predictable), the response of the public school system to the impacts of environmental TE's, on the other hand, cannot be viewed as necessarily rational or systematically related to anything predictable. As a result, instead of trying to predict the likely responses of the public school system, this paper will explore research issues associated with measuring the adequacy of a particular type of response, and examining the political and Federal policy implications of an inadequate response.

The basic organization of the paper parallels the relationship between the variables in equation (1). Part I contains a technology assessment which describes the nature of the Technology Events during this decade. Part II discusses the implications of the environmental TE's for changing the nature of educational needs and the types of educational services which are demanded by the public. Part III examines the impact of TE's on the evolution of technological opportunity, and discusses its implications for developing new forms of delivery systems. The limitations of existing forms of delivery systems in relation to the potential of the new forms is also discussed. Part IV examines some of the impediments to increased use of technology in education and speculates on the political consequences if public schools do not respond adequately to the projected environmental press for technological change. Part V examines the implications of an inadequate public school response for Federal policy and research agendas; particularly with respect to school finance equity issues.

PART I - AN ASSESSMENT OF ENVIRONMENTAL TECHNOLOGICAL CHANGE

Historically, far more technologies have been proposed and available for use in the public schools than have actually been adopted on a wide-scale basis. Educational television, teaching machines and new math are examples of technologies which, despite aggressive advocates, had little impact on schools. Examples of technologies that did impact the instructional process in public schools are books and components of vocational education. Why do so few of the available technologies actually impact education, and what particular set of conditions determines whether they will in fact be adopted? The only hypothesis which seems to explain technology adoption decisions over the centuries seems to be that technologies have major impact on public schools only if they meet both of the following criteria:

a) The technology is a cultural one (i.e., it is found in a large number of homes).
b) The technology is a primary work tool.

The former factor reduces the tendency of parents and the general public to oppose the introduction of a given technology into the schools, while the latter factor generates a demand from the public to in fact adopt the technology and provide training in its use.

This section contains a technology assessment of the extent to which microcomputers are likely to become a cultural technology and a primary work tool. The basic working hypothesis of this paper is that the greater the extent to which microcomputers become both a cultural and work tool technology, the greater the demand and need for their use in schools. Different phases and degrees of microcomputer use in the environment will be described in terms of Technology Events.

1. Limitations of technology assessment methodologies - Technology assessment (TA) is far from an exact science. The basic methodology of TA consists of interviewing "those in the know" to gather data about the basic independent variables which are then plugged into utility functions that have described the rate of adoption of "similar" types of innovations in the past. In addition to the obvious limitations of such methodology, the definition of TA is ambiguous. TA is used to represent a number of different types of analysis such as:

a) Assessing the rate of growth of technological capability.

b) Assessing the rate of adoption in society of the technological capability.

c) Assessing the social consequences of different rates of adoption of new technology.

These different types of TA form a continuum of analytic ambiguity in which the validity of projections declines as one moves from type (a) to type (c) analyses. For example, Moore's law, that the amount of circuitry that can be put on a given size chip doubles each year, has been a remarkably accurate type (a) predictor over the past several decades. Type (b) analyses, on the other hand, have been spotty in their accuracy. Assessments have consistently underestimated the use of microcomputers and overestimated the acceptance of teleconferencing and electronic fund transfer applications. The risk analysis program at the National Science Foundation represents an attempt to develop methodological conventions for incorporating type (c) analyses into formal policy debates, but there has been little success to date in anticipating the social consequences of new technology. Yet, type (c) analyses are the most critical for social scientists and policy makers. With these cautions in mind, an effort will be made to synthesize and evaluate the TA literature which focuses on small computers and their progenies: a) robots,

b) office automation, c) new forms of telecommunications, and d) information utilities and data base services. Where possible, tentative estimates of type (c) effects will be made.

2. The growing capability of computer technology- The following statement by Robert Noyce (1977), chairman of Intel Corporation, best summarizes the practical consequence of Moore's law in the recent past:

> Today's microcomputer, at a cost of perhaps $300, has more computing capacity than the first large electronic computer, ENIAC. It is 20 times faster, has a larger memory, is thousands of times more reliable, consumes the power of a lightbulb rather than that of a locomotive, occupies 1/30,000 the volume and costs 1/10,000 as much. (p. 65)

If Moore's law continues to operate, then it will be possible to put today's most powerful computers on a chip by the end of this decade.[3]

The semiconductor industry which manufactures the electonic chips is the most productive one in the U.S. today. Its productivity is estimated to have increased

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[3] There is no guarantee that it will continue to operate, but DOD's Very High Scale Integration Circuitry (VHSIC) program, and similar intensive research and development efforts in other countries, suggest that it probably will.

20,000 times during the past two decades. The total worldwide market for semiconductor products is estimated to grow from $13 billion to $60 billion during this decade (Nilles, 1980, p. 6-17). As a result of increasing productivity and demand, the cost of computing has declined very rapidly. Licklider (1980) noted that the amount of information processing that can be done per unit time by one dollar's worth of computer hardware has doubled approximately every two years since 1943, and has been doubling every 15 months since 1965. Noyce (1977) projects that the cost of computing per function will continue to decline at a rate of 25 percent per year through 1986.

The use of computers is extremely price elastic in that as the cost declines use increases. The major cost reductions cited above have made it possible to produce low cost computers; one of which now sells for only $200. As the price of computers has fallen, the size of the economic unit which can afford them has shrunk, and the number of tasks to which they can be applied has increased. Computer processors have now become so inexpensive that they are replacing mechanical components that perform measuring and controlling functions in a wide range of equipment from sewing machines to airplanes. Such replacement not only reduces costs, but also enables the functioning of the

the equipment to be changed via software modifications as opposed to expensive retooling.

The growing pervasiveness of these small computers is further enhanced by the fact that all modern telecommunications and information handling systems are based on the electronic generation, transmission, storage, reception and utilization of digital information. Virtually identical combinations of processors, memories and I/O devices can be programmed to function as telecommunications systems, data processing or work processing systems (Kalba & Jakimo, 1980).

As the capabilities of small inexpensive computers increase (some new ones have the capabilities of existing minicomputers), it is becoming possible to use them to simulate many of the human senses. Progress is being made in using digital information to represent the human senses of vision and touch. It is expected that most of the technical problems for having low cost computers perform these functions will be solved by the early 1990's. Primitive (limited vocabulary) voice input devices and speech synthesizers are already available for under $400. Engineers have already learned how to use digital representations of pictures and music to provide better quality than traditional analog techniques; an achievement which will probably soon start to be reflected in a whole new generation of digital home stereo systems.

As a result of all these existing and developing capabilities, computers are not only affecting computing, they are also changing the way we work and play, and even the nature of the economy itself. Computers, and the devices they control are, therefore, going to have an increasing role in determining how we live. The next several sections will give a brief description of these new devices, along with assessments (where possible) of their rate of adoption in the home and work place.

3. Assessment of the rate of adoption of microcomputers and intelligent video disk systems - Business Week (August 17,1981) estimates computers to be a $62 billion business. The GAO estimates that the Federal government alone spends about $20 billion a year for computers, software and related services. The computer bill for top Fortune 500 companies can exceed $100 million annually. Most of these costs, however, represent investments in large computers. The trend that is of most concern to this paper, however, is the growth of the smaller computers since most schools, homes and businesses that computerize during this decade will use this type of

computer.[4] These types of computers are usually referred to as either microcomputers or personal computers.

Nilles et al (1980) has done the most careful assessment to date of the growth of personal computers. They used two forecasting models--one with optimistic (high) assumptions about growth, and the other with pessimistic (low) ones. In addition, a Delphi panel was convened to estimate the growth of personal computers. The results of this study are displayed in Table I.

The range of estimates in Table I is quite high (a 3.5:1 ratio between the high and low estimate). It is, however, significant to note the extensive penetration into the home that is projected. Under the high projection, there will be sufficient cumulative sales to first time buyers by 1990 to have a computer in almost half the expected 85 million households in this country. Given the historic tendency to underestimate the growth of the microcomputer market, my own inclination would be to adopt an estimate between the high and the Delphi projections and estimate that 35 to 40 percent of the households will have computers by the end of this decade.[5] What this means is

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[4] The most commonly available microcomputers at this time, such as Apples and TRS-80, are 8-bit micros. Sixteen bit systems (8 - 10 times more powerful) are now on the market, and two companies have recently announced fabrication of 32 bit microcomputers on a chip.

[5] These estimates refer only to devices that are user programmable, multi-use systems, and do not include the microprocessors that are being built into appliances.

TABLE I

PROJECTIONS OF MICROCOMPUTER SALES BY MARKET

	Annual Units Sold (000's)			Cumulative Units Sold (000's)	
	1978	1985	1990	1985	1990
USC HIGH					
CONSUMER	170	3,050	8,803	7,610	39,083
EDUCATION	15	250	538	650	2,875
OFFICE	40	788	3,450	1,865	11,848
TOTAL	255	4,088	12,800	10,225	55,800
DELPHI PANEL					
	255	1,600	5,200	5,800	23,000
USC LOW					
CONSUMER	125	882	2,424	3,070	11,092
EDUCATION	15	74	150	304	886
OFFICE	85	350	604	1,587	4,041
TOTAL	225	1,306	3,178	4,961	15,999

Source: Nilles et al. (1981), P. 3-16

that by the end of the decade the computer will have become a cultural technology for the middle class, as well as the rich. The trend towards adoption of microcomputers by the middle class will be evident by mid-decade. The concept of a growing populist sentiment to acquire and use computers is also substantiated by the growing interest in obtaining information about computers. Business Week (August 17, 1981) noted that in the last 3 years, 12 new computer journals (mostly for the non-computer scientist) were published, and that advertising revenue for the 10 largest computing journals were up 50 percent from last year's levels. A recent minimally advertised four day institute on microcomputers in education, co-directed by this author, drew 280 teachers and administrators (80-90 percent of whom had never touched a computer previously). An additional 200 had to be turned away for lack of facilities. The Nilles study also estimated the number of programmers growing from 5 to 21 million during this decade--a growth rate which almost constitutes a cultural revolution.

While the educational potential of the microcomputer is very high, the potential of the computer controlled video disk system (intelligent video disk) is even greater. The video disk component adds the capability to store large amounts of data (54 thousand frames or pages on a single disk--enough to store the Encyclopedia Britannica), plus it can store still and motion pictures, text, data and sound on the same disk. These different media are all stored in digital form and can be interspersed and selectively retrieved under computer control. The system can be programmed to use greater amounts of sound and picture to instruct slow readers, and greater reliance on text for fast readers. Lipson (1980) provides a more complete description of the educational potential of the intelligent video disk. Molnar (1979) estimates that these devices should be available for about $1200 by mid-decade. Brittner, Chen and Lientz (1981) cite industry projections that 400,000 regular video disk units will be in operation by 1982.

4. Robots- One consequence of computers that is going to have major impact on the labor force is robots. Whether or not one understands that robots are a "reprogrammable multifunctional manipulator designed to move material parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks," it is clear that their use is going to accelerate during the 80's. According to Froehlich (1981), the Robot Institute of America conservatively predicts a market for robots to grow from $68 million to $210 million during the period 1980-85. Fortune (1979) estimates that sales could grow to between

$700 million and $2 billion by 1990. Despite the fact that only a total of 3500 robots were sold in the past two decades, 1850 were sold in 1980 and Business Week (1980) estimates that annual sales will increase to between 23,000 and 200,000 robots by 1990; depending upon how many additional companies enter the market. This same article also reported that GE is planning to increase its robot force from two in 1979 to 1000 in the late 80's, in a move that may replace nearly 37,000 assembly workers.

What is the likely impact on workers? A new more sophisticated generation of robots that see, feel and think is reaching maturity in the labs, and should be available in the marketplace in 3-5 years. Business Week quotes automation experts as saying that these machines could displace at least 65 to 75 percent of today's labor force. No date is given for this anticipated displacement. A recent study by Carnegie Mellon, cited by Business Week contains a more conservative displacement projection and estimates maximum worker displacement at only 7 million factory jobs (or about 25 percent of the total). It is expected that it will take till the year 2000 to displace the first 4 million, but the study suggested that it was really impossible to predict the rate of introduction.[6] Friedrich (1980) cites a forecast by the

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[6] It should be noted that the Carnegie-Mellon Robotics Institute is largely funded by industry--which probably views its interests as not heightening labors concern over worker displacement.

American Society of Manufacturing Engineers and the University of Michigan that by 1988, 50 percent of the labor in small-component assembly will be replaced by automation.

While it may be difficult to predict the exact number of displaced workers, Peter Drucker (1980) refers to the shift from the blue-collar worker to robot as inevitable. Drucker even suggests that such a shift is necessary since the number of new workers available to enter the blue-collar labor force will decline rapidly in the future. Drucker likens robots to the fractional horsepower motor which transformed industrial processes 100 years ago. It does appear, however, that the shift away from blue-collar work will be sufficiently rapid so that the skilled machinist of 1990-95 may be as employable as the migrant farm worker is today.

5. Telecommunications- Telecommunications is a major growth industry whose continued technological development is a key determinant of how rapidly and in what form, the technology applications discussed in the following sections will evolve. Jonscher (1980) notes that while all business activity (in constant dollars) had a 30 percent cumulative increase during the previous decade, business use of telecommunications increased 95 percent. The revenues of

telecommunications services industries are expected to increase from $54 billion in 1980 to $66.6 billion in 1983. With new telecommunications services expected to become available in the early to mid 80's, combined with the availability of office automation equipment, AT&T estimates that 75 percent of the $200 billion spent by business for communication in 1978 could be converted to telecommunication based electronics services; which means a potential market of $150-240 billion (in 1978 dollars) by the middle of this decade. This huge potential market explains why AT&T (ACS), and IBM along with COMSAT (SBS), are investing hundreds of millions of dollars to offer worldwide telecommunication services. Xerox had to drop out of the competition recently when it decided to shelve its XTEN system.

The new telecommunication systems under development will utilize satellites, earth stations, digital networks, fiber optic telephone cables, microwaves and/or coaxial cables. All these technologies provide the capability to transmit data at rates in excess of 56,000 bits/second, as opposed to the most commonly used speeds of 300-1200 bits/second over conventional telephone lines. In addition to high transmission speed, satellites have the additional advantage of making distance irrelevant as a factor in communications costs, while coaxial cable provides the

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potential for two-way communication. Low energy satellite stations offer the potential of a large increase in the number of frequencies available for satellite transmission. With the cost of the earth stations that receive the satellite signals expected to drop as low as $10,000 in the near future, satellite transmission potentially offers compelling savings as compared to mail or regular telephone service.[7]

6. Office automation- Office automation is to white collar work what robots are to blue collar work. Data and information are the most rapidly growing resources in organizations, and their management, acquisition, generation, distribution and analysis are costly, inefficient and undercapitalized. The number of white collar workers in this country increased nearly 100 percent between 1954 and 1974 (Yankee Group, 1979). This increase and the fact that each inquiry from a white collar worker triggers as many as 40 other messages in an organization (Strassman, 1979) means that the internal flow of information is increasing geometrically. In 1975 the average white collar employee handled 11 pages of text per day, a statistic which is expected to grow to 15 by 1990. The four file drawers of

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[7] The Yankee Group (1979) estimates that the cost of sending a 250 word letter in 1985, using XTEN, would have been as low as 5 - 6 cents; as compared to whatever the postal rate would be at that time (25 - 30 cents??).

information that each employee now has is increasing at the rate of 4000 documents per employee year (Yankee Group, 1979). At the same time, Strassman (1979) notes that the average office worker has only $2,300 of equipment support, as opposed to the $53,000 for the farm worker and $31,000 for the factory worker.

Office automation seeks to increase the efficiency with which organizational information flows are managed. Applications consist primarily of word processing, electronic mail, teleconferencing and facsimile (scanned documents) transmission. The growth of office automation is linked to the continued technological development of the telecommunications industry which provides the capability to link the individual stations and services within, and between, organizations.

While electronic office automation equipment is relatively new, the growth, particularly for word processing, has been explosive. International Data Corporation (1980) estimates that word processing will grow at a 50 percent rate, with 875,000 units installed by 1984, as compared to only 62,000 in 1979. The same study indicates that electronic mail is still in an embryonic stage and the technical options will not be sorted out until 1982, by which date there will be an estimated market potential of $200-650 million (Yankee Group, 1979).[8] To a large extent the potential market for electronic mail depends on whether the new telecommunications systems being developed become fully operational and offer economic advantages for communicating messages electronically as compared to using the postal service.

An intermediary version of electronic mail has been proposed by the post office. Under their proposal, messages would be sent electronically to a post office where the physical document is created and then delivered by a letter carrier. Indeed, the issue of who will control inter-company electronic message service is currently one of the hottest regulatory issues in Washington. Preliminary indications are that the post office will not be given a monopoly and that other carriers will be allowed to operate.

The goal of electronic mail, however, is not only to speed up the delivery of messages and facsimile documents, but to also expand the opportunities for teleconferencing. The major advantages of teleconferencing are potential savings in travel time and cost. Teleconferencing has not, however, been expanding rapidly--despite the rising costs of travel. International Data Corporation (1980) estimates the current market for teleconferencing to be only $70-80 million. While teleconferencing is an idea with a lot of potential, it has floundered in part because of technical limitations inherent in existing technology, and in part because of the traditions of doing business face to face.[9] It is not feasible at this time to make any sort of projection as to the growth of teleconferencing in the private sector.

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[8] Some companies such as Texas Instruments have gone ahead and pioneered electronic mail systems. See Craig (1981) and International Data Corp. (1980) for a description of the operation of such systems as well as a discussion of their effects on organizational process.

The use of teleconferencing for public sector agencies is even more problematic. Lucas (1981) notes that no single public agency has enough demand to support a service and there was no mechanism to aggregate demand and procure services. One approach that is currently being tried is the use of telecommunication brokers. The National Telecommunications and Information Agency (NTIA) has a charge to support several entrepreneurial organizations whose role will be to purchase services from commercial carriers and then sell these services to public agencies on a retail basis. It is still too early to tell what effect this approach is going to have.

Overall, however, it is clear that office automation in one form or another is going to proceed at a rapid pace.

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[9] For a discussion of the limitations of teleconferencing, as well as its advantages, for particular types of business meetings and activities, see Tyler (1981).

One likely effect of this automation will be to make low-end white collar workers vulnerable to job displacement (the extent to which is not clear). The major effect, however, will be changes in the way in which white collar workers work. White collar work will increasingly become information work which involves performing logical operations upon electronicized information; for clerical workers as well as managers. Porat (1977) estimates that by 1985, one-fourth of the labor force, or 25 million workers, will be involved in transferring electronic data from one form to another.

Strassman (1979) has done the most careful assessment of the implications of office automation for the nature of work and suggests the need to reorient traditional functional relationships in organizations in favor of an information middleman approach. The prototype of the information middleman is the clerk in the airlines terminal who can instantaneously arrange for a wide variety of interrelated services (services which cut across many different functional areas of the airline, and other, companies) from a single station. Strassman sees this concept extended to many other service areas such as financial management.

7. Data bases and information utilities- While the

previous section focused on using telecommunications to *manage the flow* of information and messages in business, an increasingly important function of telecommunications will be to *provide access* to information for both businesses and consumers. The issue of how to access information has become critical since the amount of information produced has been increasing geometrically, while the amount of information individuals can absorb has remained relatively fixed. Under such conditions, the market for any particular piece of information declines, and the reading, or accessing, of information becomes increasingly selective. Lancaster (1980) notes, for example, that the number of science and technology periodicals doubled between 1965 and 1977, but that the selectivity desired by readers grew faster than publishers could create specialized publications.[10] As a result, an individual may have to pay for 20 or 30 articles in a journal to get at the one paper which is of direct interest. The purchase of extraneous material may be an acceptable strategy as long as the cost of the journal is low. The costs of producing and distributing paper text, however, is rising so rapidly that a strategy of selective use of paper text is becoming less feasible. This is true not only for businesses and scientists, but also for consumers seeking information on a wide range of topics.

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[10] Lancaster cites other limitations of the present methods of physically distributing and storing text in libraries. These include; a) publishing delays, and b) the cost of storing the bulky material. As a result of the limitations of paper text, Lancaster concludes that it is inadequate to continue to support the needs of scholars.

The limitations of paper text, combined with the growing availability of computers, low cost digital storage and telecommunications, has led to the increased use of on-line (immediately accessible) electronic data bases. The electronic data base is as fundamental a development to the distribution of text as was Guttenberg's printing press. Whereas the printing press made possible the distribution of large numbers of physical copies of text, the electronic data base makes it possible to distribute text without having to distribute multiple physical copies; a form of electronic paper.

Business Week (August 10, 1981) quotes an IBM analyst as predicting that the total amount of characters stored electronically on-line will increase from the 1.7 trillion presently to 12 trillion by 1985. There is also no reason to expect the trend to slow down after 1985 given the (almost) certainty that storage, computing and telecommunications costs will continue to decline, while the need for information will increase. This rapid growth of electronic forms of information is creating new types of services and computer applications. English-like data base retrieval languages are providing the capability for non-technicians to interact with corporate data bases. This will have the effect of dramatically increasing the number of individuals who routinely use computers as a work tool. The number of services selling electronic information to businesses and consumers are also increasing, as are the technological options for accessing such data bases. Business Week (June 29, 1981) reports that there are now 800 computerized information services available, and the revenues from those systems are expected to grow from $600 million in 1981 to $3 billion in 1985. Information utilities such as the Source and Compuserve provide access to data bases via telephone lines connected to computers. Videotex transmits data to the home via television signals which are carried by antennas, coaxial cable or satellite.[11] The signals are then separated by a special decoder which enables either, the data, or the television program to be displayed. Cable systems have very high speed, two-way interactive, capabilities which make it possible for homes with computers and/or storage devices to receive data at speeds up to several million bits per second. Such high speeds make it possible to scan or transmit large amounts of information. This creates the potential for applications such as electronic home study centers or electronic publishing. An individual in Tucson could scan text from a central library in Washington D.C., or a publisher in New York, and order the pages desired to be sent electronically to the home or local library.[12] Other home applications include electronic mail and home security monitoring. Data base services also provide access to a wide range of information such as business statistics, merchandise sales, stock quotations, news services, airline schedules, etc.

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[11] While there is presently some confusion over terminology, teletext is usually viewed as a form of videotex in which there is only a one-way transmission capability.

While most of the on-line storage will be used for business applications, the number of data bases available to, and used by consumers will increase during this decade. A number of companies are now planning to market the home terminals that will broaden the base of consumers that can tap into electronic data bases. As an example, AT&T is becoming very active in Videotex. It is expected to market a $400 keypad terminal by 1984. According to the Wall Street Journal (6/12/81) Microcosmos has developed a $300 microterminal for home communication with large computers to do banking, pay bills, play games and turn household appliances on and off. The cost could drop to $100 by 1982. More sophisticated home terminals are expected to be marketed by Novation which will interconnect with the phone and television as it accesses the data base, at an expected cost of $300 by the end of 1982. Radio Shack now sells a $400 videotex terminal. If you already have a Radio Shack computer, you can access a wide variety of electronic data bases, foreign news services and have electronic mail service for an additional $30 software package. The ability to link these types of devices to coaxial cable systems, with their inherent advantages over telephone lines, is also increasing. Goldman (1980) notes that 15 million (or 20 percent) of the nation's households are now connected to cable services, with the figure growing at about 15 percent annually. Nanus et al. (1981) project that the numbers of homes connected to cable will be 50 million by the mid 90's. The same study notes that 98 percent of homes already have the equipment necessary for accessing information utilities, i.e. - televisions and telephones. Finally, it will soon become feasible to transmit satellite signals containing entertainment or data directly to the home (bypassing local tv stations). The FCC has just given Communications Satellite Corporation (a subsidiary of COMSAT) the right to offer three new television channels that would be beamed from satellites to receiving dishes mounted on top of homes. The dishes are projected to cost approximately $100-200 by 1985. As with so many of the home technologies, the initial incentive for acquiring satellite receptors will be new entertainment opportunities. The presence of these receptors will, however, begin to create new marketing opportunities which will stimulate the development of other services for home delivery via the receptor.

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[12] This type of service has led Dunn (1980) to predict that libraries will eventually become a source to print and copy electronic forms of books, as opposed to a source of items to be loaned. This conception of a public service (printing, then distribution) is similar to what the post office has proposed for itself.

As low cost equipment for accessing electronic data bases from the home becomes available, vendors will begin to increase the number of services they offer. Nanus et al (1981) found 36 consumer network services already in existence. AT&T is attempting to experiment with electronic yellow pages but, so far, has encountered stiff opposition from newspaper publishers. Sears is planning to experiment with offering its catalog on video disks for individuals with video disk players. The video disk version would add motion pictures and sound to the existing text and picture method of displaying products. Radio Shack has joined with an Ohio newspaper to provide the first eletronic newspaper. The French have announced plans to replace phone books with videotex. Urrows & Urrows (1981) report that the goal of the French plan is to put 30 million free terminals in homes by 1992 at a cost less than the $230 million presently spent to supply printed telephone books. The most comprehensive videotex system to date is Prestel in Britain, which offers 200,000 pages of on-line information, much of it free to users.

Trying to make projections about the rate of growth for information utilities and videotex is complicated by the relative newness of the service. While the evidence is clear that business is willing to pay for information, the record is less clear for typical consumers. For example, Lu (1981) notes that financial data bases such as the Dow Jones System, and legal data bases (among others) can charge $60 to $150 per hour of connect time and attract users. An upper limit for consumer data bases appears to be $15 per connect hour. MicroNET and Source cost about $4-10 per hour and currently are not profitable because there are less than 10,000 users apiece. In both cases, most users are computer hobbyists since the cost is substantially higher than acquiring the information from non-computer sources. Most of Prestel's users are businessmen, so that Lu's projection that Prestel users will grow from 10,000 in 1980 to 30,000 by 1982 does not provide a useful indicator of future consumer use. A number of experiments are currently being conducted in this country (which has lagged behind the Europeans to date in working with videotex) to determine the types of information consumers and other constituencies are interested in, how much they might be willing to pay for it and what the preferred modes of screen presentations are (see; Dunn, 1980; and Elton & Carey, 1980 for a description of ongoing experiments).

The combined trends of reduced equipment and service costs, combined with the increasing cost of travel (for shopping) and paper text material, may eventually make electronic data base accessing more attractive to consumers; particularly those who already have the necessary equipment. The Delphi panel from the Nilles et al. (1980) study did attempt to project future consumer uses. The results of this study, which are contained in Table II, project an information utility market of $50 million by the end of this decade--a substantial growth rate but hardly a major industry. If the growth rate persists, however, it would become a substantial industry in the next decade. Such an assumption would probably not be unreasonable given continued progress in reducing communication costs. Only about 7-8 percent of households are projected to be using system capabilities for electronic mail by the end of the decade. It therefore appears that while microcomputers will become a cultural technology during this decade, consumers will not begin to use them for sophisticated applications until the next decade.

8. Incentives to innovate- Since the availability of new technology in and of itself is no incentive for its adoption, incredibly powerful economic, and possibly social, forces are necessary for a society to adopt these new

TABLE II

INTERACTIVE NETWORK INFORMATION SERVICE SALES
(Millions of Dollars)

USER	1978	1985	1990
Small Business	1	6	16
Large Business	10	75	100
Education[1]	5	9	20
Home	-	10	50

Numbers denote annual sales in millions of dollars

[1] Includes Plato and similar systems

APPLICATIONS OF PERSONAL COMPUTERS

	1978	1985	1990
No. of Workers Who Use Personal Computers to Reduce or Eliminate the Commute to Work	--	0.5M	1.0M
No. of Homes That Can Be Reached Via Electronic Mail	--	1.5M	6.8M
No. of Homes Using PC's For Health Monitoring	--	50K	300K

M= Millions
K= Thousands

Source: Nilles et al. (1981), pp. 3-22, 24 technologies and incur the type of dislocative effects that have been described. What are the forces that are promoting the use of computer-based technology? Are they powerful enough to sustain the adoption process over the coming decade, or will all this new technology merely become electronic Edsels?

The two basic forces promoting adoption of the new technologies are; a) the need to be competitive in a world-wide economy, and b) the general desire to increase living standards. The lowering of trade barriers and the availability of credit have dramatically increased the amount of international trade to the point that one can talk about a global economy. At the same time, the technological and industrial supremacy that we had at the end of World War II has been eroded. The Europeans have learned how to pool their R&D resources and become competitive in highly technical products such as commercial airliners, biogenetics, alternative energy in general and nuclear energy in particular. The Japanese have also developed tremendous marketing and organizational skills.

Our overseas competitors have also become more aggressive in using their new technology to improve productivity. The aggressive Japanese robotics program has enabled their automobile workers to be far more productive than their American counterparts.[12b] This productivity advantage has had a devastating impact on our domestic auto and electronics industries. If U.S. automobile companies are to regain lost market shares, they must follow the Japanese lead; and as everyone knows, what is good for General Motors is good for the U.S.A. All manufacturing industries which want to remain competitive in a global economy are going to have to automate production as much as possible. The productivity battle is now being joined in the semiconductor industry which produces the building blocks of the new technologies. The stakes are enormous. The electronics industry currently does $100 billion in annual sales and may grow to $400 by the end of the decade (Norman, 1981). The electronics industry is even more critical than its own sales figures indicate, since almost every manufactured product in the world will be dependent to some degree on advanced electronic components. Whoever dominates the semiconductor industry dominates the world economy.

The issue of productivity enhancement is also critical to the second societal force promoting the use of the new technologies; the drive for higher standards of living. For the first time in our history productivity declined for three years in a row before it turned up again in 1980. Under conditions of declining productivity, average real income, (as opposed to inflated income) declines. The decline in productivity was a cumulative result of a decade in which business tended to invest in labor rather than in other forms of capital, such as plants and equipment (Gallese, 1980). As a result, American industry began this decade in a highly undercapitalized state.[13] The increases in the costs of labor and energy (particularly for plants with inefficient equipment) that occurred during this decade have rendered it virtually impossible to continue to increase productivity using the former labor intensive strategy. Those who want their standard of living raised, and are not threatened with job displacement, will be potent political supporters of the new technology. The efficiency advantages of the new technologies are simply too overwhelming to ignore, and are sufficiently large so as to stimulate organizations to expend the energy and resources needed to implement them, regardless of potential risks. Modern robots cost $4.80 an hour and often replace 1-5 workers, each earning $15-20 per hour. While realizing and measuring productivity improvements from information management and office automation technologies are more elusive, new techniques such as those developed at the Warton School of Business are beginning to help managers realize the benefits of these technologies (Tyler, 1981).

[12b] Although the Japanese use a more liberal definition of what can be considered a robot, Masayoshi (1981) notes that even under the more restrictive American definition, the Japanese have installed, and are producing, almost three times as many robots as the U.S.

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[13] There is an analogy to this in higher education where the NSF-DOE study (1980) noted that the quality of graduate engineering and computer science programs had declined largely because capital expenditures for new equipment had been underfunded by $750 million during the 70's.

The efficiency potentials of the new technologies may also begin to affect lifestyle patterns by changing the way we work. For example, Cole (1981) cites results which show that dispersing the workplace by substituting telecommunication access for at least part of the daily commute to central urban locations can produce a benefit cost ratio of 4:1, even before reduced transportation costs are taken into account. Others suggest the possibility of telecommunications almost eliminating the need to commute ("telecommuting") for large numbers of workers (See; Hiltz & Turoff, 1978; and Toffler, 1980 for discussions of the social implications of telecommuting). The benefits of the new technology apply not only to large corporations, but also to small businesses. Tyler (1981) notes that telecommunications provides, for the first time, the capability for individuals, or small businesses with single offices, to serve national or international markets with their "information products." Finally, not all the benefits go to business. Dunn & Ray (1979) estimate potential benefits to consumers on the order of $50 to $150 billion per year from having access to "better" information in electronic data bases.

As a result, it appears that the economic incentives to adopt the new technologies are sufficiently powerful to maintain, and in some cases accelerate, existing trends, throughout this decade. Indeed, these trends are already beginning to change the nature of the business environment.

9. Implications of the new technology for the business and regulatory environment- There are two indications of the profound changes that the new technologies are causing in the business environment. The first is the amount of corporate activity with respect to acquisitions and R&D investment. The second indicator of the significance of the technological changes is the extent to which they are requiring an almost total revision of existing regulatory policies and creating whole new legal traditions. With respect to the first, there are no data on the exact total investment being made by major corporations in developing new technology. Such investments by a handful of companies in telecommunications alone will almost certainly be in the billions of dollars before 1985. In addition, these investments do not only represent money, but also a major realignment of the competitive territoriality of the largest

corporation in this society; territorialities which have persisted for at least two decades. It is a corporate environment in which AT&T is taking aim at competing with IBM, Xerox with AT&T, IBM with newspaper publishers, COMSAT with CBS and Exxon with everyone.[14] In addition, as businesses become more dependent on computers and telecommunications, traditional distinctions will disappear since computers can be programmed to perform multiple functions. This is happening to a large extent in the financial services industries as insurances companies become stock brockers and stock brokerage houses compete with banks. IBM, in recognition of the enormous stakes that exist in telecommunications, has overcome its traditional resistance to being a regulated business and is now subjecting itself to FCC oversight. AT&T, on the other hand, the largest regulated business in the world, has apparently reversed government policy and will be allowed to set up unregulated subsidiaries. Tracing the regulatory implications of changing technology is way beyond the scope of this paper; which is unfortunate since they are quite intriguing.[15] The following passage from Tydeman et al (1980), discussing the regulatory implications of videotex is, however, illustrative:

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[14] Exxon's strategy is that of venture capitalist whereby it uses its oil revenues to foster high technology concepts and then incorporates the successful companies, such as Zilog, as subsidiaries.

> Videotex brings together a highly regulated industry (communication) and a relatively unregulated industry (data processing and computing). Under the current law, the FCC has principal regulatory jurisdiction over broadcast teletext. This body is currently wrestling with the regulatory dividing line between data processing and communication, a line that videotex straddles. But videotex may also be involved in some way with other governmental bodies, such as the Federal Trade Commission, the Justice Department, the Copyright Tribunal, the National Telecommunications and Information Administration, the courts, state public utility commissions, and the Comptroller of Currency. The uncertainty here begins with uncertainty about who regulates whom, but even more important are questions about the nature of the regulation. Who monitors the various regulations? How are they implemented? What are the implications of such regulations for suppliers of the service, information providers, information content, and users of videotex? In particular, what areas of regulation are likely to be in conflict or to impinge upon each other? (pp. 6,7)

The resolution of these types of regulatory questions has fundamental implications for reshaping the political arrangements within and between levels of government. The new technology also raises questions about the basic organizational structure of government. In the Federal Government, for example, the FCC sets communication policy, NBS and GAO set computer procurement policy, OMB manages data acquisition, and NTIA is in charge of telecommunications policy. Technology has, however, rendered these functional categories non-distinct.

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[15] For comprehensive discussions of the regulatory policy implications of changing technology, see Tydeman et al (1980) with respect to videotext, and Yurow (1981) for telecommunications policy.

10. The basic scenario of technology events- Previous sections have reviewed assessments of the environmental impacts of technology during this decade. This section will consolidate that information into technology events that describe the nature and extent to which computers will become a cultural and primary work tool during this decade. The basic pattern that emerges from the technology assessments that have been reviewed is that business use of new technology seems to be half a decade ahead of consumer use. Business is now making heavy and rapidly increasing use of basic applications in data processing, office automation and robotics. Business use of more sophisticated applications such as distributed data processing, electronic mail or teleconferencing will probably not occur on a large scale till the second half of this decade. Large scale use of even more sophisticated techniques, such as the fully

automated assembly line, direct voice input and telecommuting, will probably have to wait for the first half of the next decade. This phasing in of technological change in the business sector is going to occur because of the need to change traditional practices if the potential benefits of technology are to be realized. A phasing in approach will also result from the need for additional technological developments in telecommunications, computers and artificial intelligence.

The scenario for technology in the home is less clear. Large numbers of computers will appear in (maybe in as many as half) the nation's households by the end of this decade. These will be used largely as stand along units purchased mostly (initially) for entertainment purposes, interconnected to the television. Low cost interconnection capability to telephones, hi-fi systems, cable and satellite receptors will become available, and/or start to be used, by mid-decade; again largely to integrate home entertainment opportunities. Additional home applications will include home shopping, bill paying and energy management. The extent to which these powerful capabilities will be used for educational purposes, or for linking with electronic data bases, remains to be seen; although such use will increase in the latter half of the decade. Also unknown are the mechanisms by which such substitutions will begin to occur.

Will the transition of computer use from entertainment and convenience tool to an educational device result largely from the desire of computer literate parents to transmit these skills to their children? Will it result spontaneously from children's natural curiosity about devices which provide pleasure? Can, and should, government play a role in facilitating such a transition?

Viewing the use of computers in the home and workplace as a phased-in process undergoing transition to more sophisticated applications leads to the question as to when this transition will occur. The date that keeps appearing in the literature as the one in which new technological opportunities or trends will arise is 1985. For example, in addition to the literature already cited, Markoff (1981) cites a recent report by the Stanford Research Institute that concludes that 1985 will be a watershed year in which the following will occur:

a) The price of a computer equivalent to an Apple will drop to $500.

b) Microcomputers will be incorporated into television sets.

c) AT&T will enter the market of selling data base services and home terminals.

d) Home purchase of microcomputers will exceed those for business.

As a result, 1985 will be viewed as the key date separating the time spans for the projected technology events of this decade.

Synthesizing the subjective data of multiple technology assessments into discrete categories is a somewhat arbitrary process. There does, however, appear to be a definite pattern in the multiple studies reviewed. Table III contains a description of the projected technology events for this decade. In terms of the basic concern of this section, Table III suggests that computers are already a primary work tool whose prevalence in the workplace will increase throughout the decade. Computers cannot, however, be considered a cultural technology until the 1985-86 period when they will begin to make substantial penetration into middle-class homes.

The basic implication of Table III for policymaking purposes is that computers will meet the dual criteria of being a cultural and primary work technology by 1985-86. As a result, consistent with the hypothesis put forth at the beginning of this section, the 1985-86 period will be the projected point in time when major educational needs with respect to the use of technology will exist in the

TABLE III

TECHNOLOGY ASSESSMENT (TA) OF SOCIETAL USE OF MICROCOMPUTERS

	1980-1985	1985-1990	1990-
Cultural Technology	Increasing use for entertainment and simple applications.	Found in about 40% of homes increasingly used for accessing electronic data bases and home education.	Extensive use accessing electronic data bases and home education. Found in the majority of homes.
Primary Work Tool	Extensive use for technicians and clerks. Minor implications for blue collar work.	Growing use by non-technician managers, some replacement of blue collar work.	Basic tool used for managing communications and conferences. Large scale replacement of blue collar and other routine work.

environment and when significant external demands to provide such training will impact the schools. This provides a cushion of 3-4 years for the public schools and Federal policy to prepare for the needed adjustments.

PART II - THE IMPACT OF NEW TECHNOLOGY ON EDUCATIONAL NEEDS

Throughout the history of our nation, whenever new technologies became cultural technologies and/or a primary work tool, schools have had to expand their curriculum. The production line generated vocational education, the car generated driver education and the printing press created the need for schools to teach reading. It can therefore be expected that as the computer becomes both a cultural technology and a primary work tool during this decade, it will generate the need for new educational services. The changes in the home, workplace, and society in general will cause a shift or expansion in the kinds of educational services that are needed and demanded. At this point in time it appears that the new technology will generate the following curriculum needs:

a) The need for workers to have the skills necessary for jobs in the changed labor market, as well as the need to have a labor force with adequate technical skills.

b) The need for consumers and parents to obtain needed, or useful, services from the new technology.

c) The need for voters to make informed choices about the myriad of social and political issues related to technology that will have to be resolved in the coming decade and a half.

The following sections will discuss each of these needs as well as their curricular implications.

1. The changing labor force- As suggested in the previous section, this decade will be one in which substantial inroads will be made in automating routine work processes. Blue and white collar work is going to shift away from literal or repetitive tasks towards more flexible and logical interactions with electronic forms of information and information workers. Simple office and factory work is going to be replaced, much as the farm laborer was replaced by the tractor.

The issue of whether this new automation will merely shift the nature of work, or will substantially reduce the number of jobs is not clear. To date, automation has not reduced jobs. After reviewing the optimistic and doomsday predictions on the employment effects of the new technologies, Nilles et al (1980) concluded that there was not as yet any basis for determining what impact there will be on the total number of jobs. There are, however, much better data with respect to the shifts which are occurring in the labor force. Economist Marc Porat (1977) has done the most careful and comprehensive (albeit controversial) analysis of the information sector of the U.S. economy. Porat concludes that the information sector of the economy grew from 15 percent of the workforce in 1910 to over 40 percent by 1970. What is even more significant is that Porat found that information workers earned over 53% of all labor income in 1967; which means that we no longer have an industrial economy. It is now an information economy. Just as agricultural workers, as a percentage of the total labor work force, continued to decline once we entered the industrial phase, the percentage of the labor force employed in manufacturing will continue to decline now that we have become an information (post-industrial?) economy. Porat estimates that 50 million information workers (approximately 50 percent of the projected labor force) will be needed by 1985.

There is a good bit of circumstantial evidence to support the existence of a trend towards information work. Nilles et al (1980) did a spot check of 5,000 advertised job openings in the classified section of the Los Angeles Times and found that 75 percent were for knowledge workers. This same study cites a finding by Arthur Luehrman, of the Lawrence Hall of Science, that 80 percent of new jobs in

Pacific Gas and Electric Company require computer understanding. As early as 1971, 57 percent of the jobs in the then fledgling semiconductor industy could be classified as information work, with only 36 percent employed in semi-skilled jobs. Changes in skill requirements are also occurring in the traditional manufacturing industries. Lund (1981) found that when metal-working jobs were replaced by simpler light electronic assembly (as electronics replaced mechanical parts in products), production and service jobs tend to be deskilled but the work of engineers and supervisors becomes more demanding. Hymowitz (1981) reports that G.M., which now employs one skilled worker for every 5.6 assembly line workers, may need a one-to-one ratio by the year 2000.

Such employment trends suggest that education is going to be even more of a pre-requisite for employment in the future, and that a significant portion of the workforce is going to have to acquire new work skills and habits in the near future.[16] Much of these new skills will relate to using technology, and a large percentage of the growing non-manufacturing workers are going to have to begin to perform increasingly sophisticated technical operations. It is fairly easy now for secretaries to adapt to office automation since, in its present form, it only substitutes one form of typing machine for another. The grammatical and vocabulary skills of the clerks are still the primary determinant of office productivity. There are, however, systems currently on the market that check text for spelling errors and make automatic corrections. The next generation of word processors will automatically check spelling and some aspects of punctuation. By that time, large numbers of information workers will find it advantageous to use the capabilities of the word processor to compose and edit the original versions of their work by themselves. At that point, the clerical workforce will have to take on additional, or different, functions in order to justify their existence. Such functions will likely involve forms of non-routine interactions with data bases which will require engaging in linear logic technical operations.

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[16] While this has obvious implications for continuing education needs, that issue will be ignored in favor of a more fundamental one, i.e. can public schools reorient their curriculum sufficiently to prepare individuals before they enter the workforce?

While traditionally routine work becomes more technical, there will also be a growing demand for those who are more commonly viewed as technical workers; engineers and programmers. Anders (1981) notes that while there is currently a demand for 54,000 additional programmers, the nation's colleges only graduated 11,000 people with bachelor's degrees in the field last year. At a time of high youth unemployment, high school students with a good background in progamming may be able to earn as much as a beginning college professor. Anders (1981) reports that the demand for programmers may double during this decade, while Business Week (Sept. 1, 1980) estimates that it may triple to 1.5 million by 1990. There will also be an increasing demand for individuals who can service and maintain the new technology.

The curricular implications of the above employment trends for schools are as follows:

a) Strengthen the mathematics and science curriculum, particularly at the elementary levels.
b) Substitute discovery activities designed to stimulate logical thought for rote activities in large portions of the curriculum; particularly in the areas of science and math.
c) Provide all students at least one opportunity to produce a major project on a computer.
d) Strengthen the curriculum in the areas of computer programming and electronics.

2. Consumer needs - Consumer use of the new technology will take three main forms:

a) Taking advantage of entertainment and educational opportunities.

b) Electronic shopping.

c) Engaging in self-service activities.

With respect to the latter, Ernst (1981) notes that the key to improving productivity in the growing service sector is to induce consumers to engage in self-service activities in return for convenience. An individual using an automated banking teller is really performing operations that would otherwise be performed by a teller--so in a sense the consumer is being conned by the term. The consumer is really undertaking a greater responsibility in the transactions than previously in return for the conveniences of quicker service and around the clock banking. Of course, the greater the gain in convenience desired by the consumer, the more complicated the system must become; both for the system designer and the consumer user. The technical sophistication of consumers could thus become a limiting factor in improving productivity in service sectors, or in limiting the benefits which they can obtain from technology.

There is already some indication that consumer lack of familiarity with branching (as opposed to sequential) searching techniques are creating problems in their accessing electronic data base. Accessing information for most individuals currently consists of using the dictionary and reading a newspaper. Looking for information in a dictionary or newspaper, however, is essentially a two-step sequential process in which (in the former case) you search for the letter and then search within the section containing that letter. Using the searching capability of the computer may require the user to specify ten different conditions in response to a series of menus which appear in sequence, with each new menu usually selected on the basis of responses to previous menus. Lu (1981) notes that most people are unwilling to go through more than two steps to find a piece of information. A study of Holland's interactive videotex system found that users initiated search procedures correctly in only 56 percent of the attempts, and 30 percent of the searches failed completely.

The major curricular implication of this section is the need to provide the opportunity for students to engage in data base searching activities on a computer. Such activities could be provided by a computer based library catalog system, or by providing students access to computer network services such as GIS (Guidance Information System) or an information utility such as SOURCE. Prince (1981) describes the impact of the latter type of program.

3. Voter literacy- Voters are going to be asked to

express preferences on a wide variety of issues related to the role and use of technology in society. If a Luddite type reaction is to be avoided, it is important for voters to have at least some familiarity with the technologies, as well as some knowledge for forming the basis of weighting the pros against the cons.

The curricular implications of voter needs are for computer literacy programs that would not only provide some basic knowledge about the computer and technology, but would also provide students with access to professionals in the field. It is also important for such programs to provide opportunities to explore the implications of using the new technologies, and to integrate such activities into general citizenship, civics and social studies activities and programs.

4. To what extent is the existing school curriculum adequate for meeting the needs of a technological society- With respect to the educational needs discussed in the previous sections, the most critical one over the short term is that of providing adequate technical training. How adequate is the existing curriculum in that regard? Izaak Wurszup, at the University of Chicago, has received a lot of national attention the past few years for his assertions that the math programs in Russia were far

superior to our own; and as such, Wurszup and others argue that such a math gap constitutes a national security issue which will enable the Russians to achieve technological superiority over us. In response to such assertions, a joint NSF-DOE presidential task force was convened by Carter to examine whether existing math and science programs were adequate to support the technological development of this country.

The task force concluded that our system is producing adequate numbers of scientists to meet projected needs in most areas. There are some worrisome shortages expected in the fields of computer science and engineering. Of greater concern to the task force, however, was the deteriorating quality of math and science programs in the secondary schools, combined with declining standards and requirements for non-science majors. The report noted:

> ...the general quality of science and mathematics instruction at the secondary level has deteriorated since the 1960's, as has the scientific and mathematical competence of students who are not motivated towards careers in science and engineering...(p. 7)
>
> ...There is today a growing discrepancy between the science, mathematics and technology education acquired by high school graduates who plan to follow scientific and engineering careers and those who do not. Scientific and technical literacy is increasingly necessary in our

> society, but the number of our young people who graduate from high school and college with only the most rudimentary notions of science, mathematics and technology portends trouble in the decades ahead...(p. VII)

The task force noted that a number of countries had reformed their curriculum in the belief that increasing the degree of technical emphasis would increase their international economic competitiveness in a technological age. Japan, Germany and the U.S.S.R. have much more stringent math and science requirements for non-scientists and make greater use of those trained as scientists in public and private sector managerial positions.[17] After noting that Britian's declining ability to compete in international trade was probably due to the decline in its engineering training, the task force attempted to assess the extent to which declining emphasis on science and math in this country could jeopardize its future. The task force concluded:

> Comparisons between the U.S. and our international competitors suggest that our eminence

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[17] As an example of the sharp differences in educational focus, all college bound secondary students in Japan take four mathematics courses, and three natural science courses regardless of whether they intend to be scientists.

> in basic research is secure. However, our ability to apply technology to our military and industrial pursuits may well be hampered by the relatively low level of scientific and mathematical competence of our non-scientists and, in some respects, by the apparent cooling of science interest among our students generally.
>
> There is anecdotal evidence from U.S. industry that in some highly technical areas the time required to produce a product has increased as workers' base level of understanding of science and mathematics has decreased over the past decade... (p. 137)

The consequences of a sharp dichotomy between the training of scientists and non-scientists also extends to the managerial level. The U.S. views the scientist as a researcher, and the manager as a lay person. The Japanese, on the other hand, overproduce scientists for research needs and place the excess in managerial positions. The task force noted that 50 percent of Japanese managers in the public and private sectors have science backgrounds as opposed to our reliance on individuals with legal and finance backgrounds. This greater familiarity with technology at the managerial level is related to the greater willingness the Japanese companies have to adopt new technology at the expense of short term profits, and for their government to subsidize efforts to develop new technology.

Finally, while the task force concluded that the technical training for scientists appears to be adequate for future research and development needs, there were notable exceptions in engineering and computer science. The latter shortage is beginning to constrict the growth of the computer industry. Business Week (September 1, 1981) estimates that the shortage of programmers could restrict the growth of the data processing industry by a third, or $30 billion, in 1983.

While it is not certain that inadequate technical preparation of non-scientists will erode our international competitiveness, there is reason for concern even if the premise is only partially correct. There will be a temptation, when proposing solutions to this potential problem, to draw analogies to the Sputnik era. There are, however, fundamental differences between the circumstances and needs that prevailed in the late 60's and now. These differences are summarized in Table IV. The basic differences are that the educational goals of the Sputnik era were fairly discrete, i.e. train more scientists, and they were enacted during a period of expansion. The current need to strengthen the technical knowledge of the non-science major is more diffuse, and occurs during a period of contraction. As a result, a simple add-on program approach whereby math courses are added, or the gifted students are

TABLE IV

A COMPARISON OF CURRICULAR REFORM IN THE SPUTNIK AND POST - 1985 ERAS

	Post-Sputnik Era	Post-1985 Era
Focus of Education Need	Train Scientists	Prepare non-scientists for a technological age.
Rationale for Government Intervention	National Defense	Maintain competitiveness in the global economy.
Perceived Competitors	Russia	Russia, Japan, France, Germany
Status of Educational System	Expansion	Contraction

given computers to work with, or extra textbooks are provided, does not address the current need. A more comprehensive curricular reform is needed in which the *average* student is exposed to more science, math and computer use.

Achieving such comprehensive reform is particularly difficult at the critical elementary levels where student attitudes are formed. The difficulties arise largely because of the lack of technical training and skills among teachers. Papert (1980) notes that most math instruction at the elementary level is devoted to rote arithmetic as opposed to learning about relationships between quantities and events, such as motion, that are intrinsically interesting to kids.[18] In addition, math is taught largely by individuals who are terrified by the subject and in ways that appeal only to students with obsessive compulsive personalities. It is a case of the frustrated teaching the impressionable via the same techniques that produced their own frustrations. Trying to improve math and science instruction for most students, while also introducing computer concepts and use into the elementary curriculum, implies a far more comprehensive change than was ever contemplated in the Sputnik era.

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[18] Papert notes that it is not till college calculus that students get to relate mathematics to dynamics and motion. Few students are willing to wait, and accumulate seemingly uninteresting information for twelve years in order to have an opportunity to learn about what is of present interest to them, and for which so many fun activities exist outside the classroom.

5. Summary - There appears to be two unmet educational needs resulting from changing technology. These include the need to; a) train more computer programmers, and b) increase the technological sophistication of non-scientists. While it can't be proven conclusively that these needs are directly related to the national interests of military preparedness and economic expansion, there is anecdotal evidence that they are. This implies a role for Federal policy. There is, however, a fundamental difference between the two needs in terms of policy requirements. The first need is discrete in nature and requires the expansion of existing programs for a particular category of student. The second educational need implies a far more comprehensive type of curricular reform which requires the creation of new services, and the modification of existing services, for most students. If it is indeed necessary to introduce such curricular change the obvious questions are; a) Can it be done under the present conditions of contraction?, and b) What is the best way to try and do it?

PART III - ALTERNATIVE APPROACHES TO DELIVERING EDUCATIONAL SERVICES

The previous section suggested that changing technology was generating new educational needs which had implications for comprehensive curricular reform. It was also suggested that such reform was in the national interest. Attempting to address such needs are, however, complicated by the contracting nature of education and the history of reform attempts during the 60's and 70's. With respect to the latter, Federal Policy was successful in stimulating districts to adopt a variety of add-on programs. Federal policy was not, however, very successful in stimulating reform of the "general" program for the "regular" students.

The purpose of this section is to explore how technology could be used in this decade to assist in the delivery of educational services, both with respect to education in general, and curricular reform in particular. Technologists tend to address this issue by simply advocating giving each child a computer. Such a pure technology approach, however, ignores other disciplinary concerns. This issue of what constitutes an appropriate delivery system for stimulating reform has been asked in the social science literature for the past decade and a half with respect to a wide variety of other interventionist policy initiatives. Such prior research is reflected extensively in the literatures on politics, evaluation and innovation diffusion. As a result, technology related curricular reform will not be viewed in a conceptual vacuum. Instead, an attempt will be made to link such reform to existing knowledge about the outcomes of previous policy attempts to promote reform. Specifically, existing literature will be explored for insights into the following questions:

a) What are appropriate characteristics for a delivery system designed to meet the curricular challenge of changing technology if the mistakes of previous reform policy initiatives are to be avoided?

b) Given expected levels of technological development and opportunity, what new forms of delivery systems will become feasible during this decade?

c) How do the characteristics of the new forms of delivery systems compare to the traditional one, and which system is most appropriate for promoting technology related curricular reform?

1. A critique of traditional approaches to policy formation and delivery systems- The major policy thrusts in education over the past decade and a half have focused on

improving the effectiveness of education by shifting the distribution of educational funding towards providing compensatory services for the disadvantaged, and shifting allocation priorities to stimulate the adoption of innovative practices.[19] The basic delivery mechanism was to use a variety of dissemination strategies for those programs and techniques which evaluation demonstrated to be effective. The dissemination strategies shifted from demonstration programs and centers to the use of linking agents and the national diffusion network concept. The grand conception was to emulate the success of the agricultural movement by adopting an R&D perspective to improve education.

Some argue that we have not been able to develop techniques for improving educational effectiveness and that the compensatory policies were largely failures. There are, however, an increasing number of studies such as Glass and Smith (1978), Summers and Wolfe (1977), Miller (1981) and Wendling & Cohen (1980) which find significant improvement effects from school based variables and compensatory efforts. Yet, even if compensatory programs can be shown to improve the effectiveness of education, improving school effectiveness would still not be a realistic policy goal for the 80's for the following reasons:

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[19] The term "effectiveness" is used to refer to levels of attainment with respect to learning outcomes, while "efficiency" refers to the level of goal attainment per unit cost. Efficiency can be improved by maintaining costs while improving effectiveness, or by reducing costs while maintaining effectiveness. It is the latter strategy which is the focus of this article. This distinction between goals can also be applied to effective measures.

a) The unavailability of resources to carry out the fiscal requirements of the compensatory policies in the absence of major gains in efficiency.

b) The absence of adequate delivery systems for improving effectiveness.

Under the contracting fiscal conditions likely to prevail in the 80's, efficiency gains are a prerequisite for improvements in effectiveness for education as well as for General Motors. Fiscal projections such as Kirst & Garms (1980) tend to show educational revenues unable to rise as rapidly as inflation throughout this decade. While supporters of education and advocates of special causes decry such trends and attempt to develop strategies to entice additional funding from the political process, the simple reality is that under conditions of declining societal productivity, new resources can ultimately be generated only by efficiency improvements.

None of the existing methodologies for improving school effectiveness, however, currently provide the potential for achieving major gains in efficiency. Even when compensatoy programs improve effectiveness, they do so at the expense of increased costs and therefore tend not to improve efficiency. Trying to improve effectiveness under conditions of declining societal productivity is a Catch-22 situation wherein pursuing such policies reduces the possibility of generating the resources needed to implement the policies. Without efficiency generated slack resources it will be impossible to provide compensatory efforts to meet special needs, or strengthen programs in the arts, humanities and sciences. It will be impossible to implement any reforms, and education will continue to contract around basic services.

Another constraint to successful implementation of effectiveness enhancement policies, even where the knowledge of appropriate instructional strategies exists, is an over-reliance on the transfer and utilization of information among teachers. It is, however, difficult (impossible?) to find precedents in any field where it has been possible to diffuse new techniques throughout a highly labor intensive activity with fairly fixed financial incentives simply via information transfers. In most historical examples where diffusion was successful in improving the quality of services and products, the knowledge diffusion was accompanied by an economically compelling technology to reduce dependence upon labor, or an increase in the capital support behind each worker. The contrast between the U.S.

and U.S.S.R. experience in agriculture is a case in point. Whereas this country has been extremely successful in increasing agricultural production, the Soviets, with their reliance on labor intensive collective farming, have found it difficult to raise production despite intensive efforts to get farmers to adopt new techniques. If diffusing knowledge while maintaining the labor intensity of the service doesn't have much effect in agriculture, it isn't likely to be successful in education.

There have also been shortcomings in the innovation literature upon which much of the design of delivery systems have been based. One limitation which has received a lot of attention is the presumption that adoption of an innovation is synonymous with implementation. Berman and McLaughlin (1978), and Hall (1977) have shown that adoption and implementation are separate processes. Another problem is that the innovation literature has assumed that if implementation of an innovation is achieved, then the benefits associated with a given level of implementation are automatically tansferred across sites. Despite all the work in innovation and evaluation, however, there is virtually no evidence that if district Y implements a program that has previously been demonstrated to produce learning improvement in district X, that district Y will experience learning improvement (even if implementation effects are controlled for). The evaluation of Follow Through, which has been the only attempt to date to link implementation quality to learning outcomes, found large variances in results among sites that had similar degrees of implementation of the same program.

What does this mean in terms of the viability of using knowledge dissemination strategies to improve the effectiveness of schooling? First, if learning outcomes are highly independent of program implementation, then there is not likely to be any systematic effects on learning improvement from the activities of programs such as the National Diffusion Network (NDN) and the Fund for Postsecondary Education. These programs seek to identify, and/or develop, practices that work, and then disseminate them through linkage agents. The "validated" program concept of the NDN is of little utility if the benefits do not have a high probability of transferability. This issue of benefit transferability tends to be ignored by the recent evaluation (Pelavin, 1979) of the Fund for Postsecondary Education, and by the current research on knowledge utilization and linkage agents such as Emerick & Peterson (1978). These studies focus on the diffusion of innovation, or study the process of attempted diffusion, rather than the impact of such diffusion on student outcomes. Such studies ignore the impact of implementation activities on learning, and falsely assume that the benefits of innovation are automatically transferred.

The second problem with using knowledge dissemination strategies as the primary means to improve effectiveness is that if there are three stages of innovation diffusion (adoption, implementation, and effectiveness improvement) which operate independently, then the probability of increasing effectiveness becomes very small. For example, if the probability of the adoption of a "validated" practice is .2, and the probability of the adopted practice being successfully implemented is .2, the probability of the innovation reaching the implemented state is .04. If the probability of the implemented innovation actually improving learning in other districts is also .2, then the probability of the diffused innovation impacting effectiveness is only .008. Eight chances in a thousand (or 160 out of 20,000 districts experiencing increased effectiveness) is not a sufficiently high probability on which to base policy.

The probabilities are of course only estimates. The best available data, however, suggests that innovation adoption is an almost random event, and the probability of successful implementation extremely low. For example, Duchensnueau, Cohn & Dutton (1979) found virtually no correlation of tendencies within, or between, firms in the shoe industry to adopt a series of innovation. Berman and

McLaughlin (1978) could find no examples (p=0) of Title III innovations that were implemented once demonstration funding was withdrawn.[20] The low probability for successful implementation is not suprising given that many progams are couched in generalities rather than in terms of specific activities, and that implementation itself depends on a series of probabilistic events related to the behavior of individuals.

The major strategy for increasing the probability of appropriate implementation behavior by individuals has been inservice and university training programs. The assumption has been that if individuals are given knowledge they will apply it. The major resources expended for such training, however, seems to have had little impact on implementation quality. As a case in point, administrator training programs are dominated by efforts to train individuals to supervise and evaluate the instructional process. Such activity is indeed essential for successful implementation of new instructional efforts in the school. Studies of the actual behavior of administrators such as Blood, et al. (1978), however, tend to find that, despite their training, administrators seldom evaluate instructional activities. In a similar vein, Berliner (1980), commenting on the cumulative impact on teaching learning theory to teachers, concludes:

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[20] Yin et al. (1978) found that 42% of the innovations they studied in a variety of public agencies became highly routinized. Yin attributed the discrepancy between their findings and those of Berman and McLaughlin to the fact that Berman and McLaughlin studied innovations of organizational process while they focused on hard technological innovations which were locally initiated. Since innovations in education seldom include hard technology, the suggested probability of .2 for implementation may be an overestimate.

> Teachers do not hold learning theories. Despite what they have been taught, they are smart enough to realize that most learning theory is bunk! (p. 215)

The extensive supervision establishment tends to respond to such criticism by arguing that a new approach to conceptualizing and teaching supervision would solve the problem. The knowledge utilization school argues that more basic research is needed to understand the conditions under which individuals apply provided knowledge. Common sense, however, suggests that if the knowledge dissemination effort to date, as represented by research and supervision courses, have not yet had a demonstrable impact on school effectiveness, or even on administrative behavior, it is not likely to do so in the future.

A final limitation of the delivery systems used in effectiveness enhancement policies is that teachers are victims rather than beneficiaries. More often than not the procedures that are set up are designed to help simplify the administrator's tasks in placing additional responsibility on teachers. Traditional models of inservice tend to assume that if someone understands how to do something and wants to do it, then they will do it. Such a position ignores the possibility that the individual may not have the resources necessary to do the job.[21] It is fairly common to find teachers being pressured to engage in reforms, such as individualized instruction, for which no adequate technology exists for assisting them in doing it within the constraints of the (time and energy) resources available to them. Herbert Simon (1971) has noted that if an effectiveness enhancement system doesn't simplify tasks, then it tends to be ignored by the targeted individuals.

Effectiveness oriented policies have large constituencies in the reform, evaluation and supervision communities. They also have high degrees of political saleability. Unfortunately, they are not likely to work for the myriad of reasons already discussed; regardless of how much money is spent for basic research. In addition, delivery systems which rely primarily on knowledge dissemination (conceptual implementation) are not likely to be effective in promoting the implementation of curricular reform.

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[21] Pogrow (1980) has differentiated between conceptual implementation approaches which attempt to promote adoption of innovations by disseminating information, and physical implementation which focuses on providing tools that actually perform all, or part, of the innovation.

2. Alternative approaches to policy formation and delivery- If schools are to adapt to the educational needs of changing technology, curricular offerings need to be expanded under conditions of constrained resources and shortages of qualified personnel. Given the discussion in the previous section, the primary focus in interventionist policy under such conditions would need to shift from effectiveness enhancement to efficiency improvement. Desired characteristics of the accompanying delivery system would be to supplement, or replace, reliance on knowledge dissemination activities with automated systems that are physically capable of providing educational services. Feller, Menzel & Engel (1974), Lambright (1977) and Yin et al. (1978) all found the rate of implementation for hard technology innovation to be significantly higher than for other types of innovations in the public sector. A related goal would be to use hard technology systems to simplify the management of classroom activities.

The only way to expand the curriculum under the conditions of constrained resources likely to prevail throughout this decade is to use the very technology that is creating the need for expanded services to deliver educational services. The basic goal of such a delivery system would be to use technology to improve the efficiency with which educational services are provided by focusing on ways to reduce costs while, at least, maintaining existing levels of effectiveness. Technology would not be viewed as an added cost but as a substitute for labor under conditions where such substitution would not detract from student learning. The traditional mission of evaluation, to help understand how to improve effectiveness, would be extended to also provide guidance on how not to impair effectiveness.

To the extent that efficiency improvements could be made in the delivery of basic skills, resources would be freed up to help schools reverse the contraction of curriculum that is occurring and to provide compensatory help in an effort to increase effectiveness. Slack resources could also be used to increase the technological relevance of the curriculum. Technological substitution also offers the advantage of potentially requiring a less complex delivery system for program implementation, and for providing teachers with concrete tools to simplify their implementation tasks.

There are basically two different approaches that can be used to incorporate technology into educational delivery systems. In the first approach, which will be referred to as a low-leverage system, technology is used to support and supplement the traditional activities of the teacher. Under such an approach, teachers coordinate the use of computers in a classroom with their own instructional activities in order to expand the total amount of educational activities that are provided. In the second approach, which will be referred to as a high-leverage system, technology is used to supplant the role of teacher. In this latter type of delivery system, educational courses and activities are delivered directly to the home or classroom without intervention by an on-site teacher.

Table V summarizes the differences between the traditional, and the technology based, delivery systems. The next several sections describe the technology based delivery systems in greater detail.

3. The feasibility of using low-leverage delivery systems - Those who oppose the use of technology in education rightly point to the critical role that teachers can play with respect to the intellectual and social development of children. A number of educational innovations, such as individualized instruction and open classrooms, sought to enhance the probability that teachers could indeed fulfill such potential. The available technologies, however, did not provide adequate means for teachers to accomplish the required tasks within the confines of the school day. As a result, classroom research such as Berliner (1980), and the studies cited by Heuston (1980), tend to show that students receive virtually no individual-

TABLE V

A COMPARISON OF DELIVERY SYSTEM CHARACTERISTICS

	TRADITIONAL	LOW LEVERAGE	HIGH LEVERAGE
Primary Policy Goal	Improve effectiveness of traditional services	Increase service per unit of cost	Minimize cost of services provided
Secondary Policy Goal	Maximize use of existing networks	Improve effectiveness	Improve effectiveness
Technology Used	Social contact, in-service training	Computers plus social contact	Computers plus telecommunications
Prime Means of Instruction	Teacher	Teacher plus computer	Telecommunicated teacher
Focus of Delivery System	Conceptual implementation of reforms; i.e., teaching teachers how to do it. Transfer of social science information	Physical implementation of new services; i.e., providing an installed version, using social science to construct educational software	Physical implementation
Conception of Teacher	Teacher	Teacher and manager with technological support	Inefficient form of instruction
Fundamental Educational Unit	School or classroom	Educational activities in classrooms	Courses
Mode of Political Influence	Interest group lobbying	Environmental collapse	Environmental collapse

ized attention (less than one minute per day) in classroom settings. Attempts to increase the amount of individualized attention that teachers can provide students have focused on reducing the student-adult ratio. The work of Glass & Smith (1978), however, suggests in order for significant learning improvements to occur, class size must be reduced to such an extent, that labor intensive approaches to increasing effectiveness are financially unfeasible.

Under a low-leverage delivery system, technology would be used in the classrooms to help deliver some of the instructional activities that do not require constant teacher intervention. In other words, computers would enable students to engage in self-service learning activities much as the adult uses automatic tellers. Computers would also be used to assist the teacher in classroom management activities and student diagnosis. The goal would be to increase the amount of intensive educational activities available to students while freeing teachers to concentrate on those types of interactions which are uniquely human.

The issue of whether such a computer intensive classroom is feasible is a function of the following factors:

a) Technological opportunity

b) Demonstrated effectiveness

c) Structural barriers to implementation

Before reviewing the research evidence, it is important to note that each of these factors have different analytical properties. Technological opportunity is a function of time. That is, as technology progresses and costs decline, it becomes more feasible to consider using technology in a particular way. As a result, cost estimates, and conclusions about technological opportunity, that are reported at a point in time are relevant only to that point in time; and are not relevant to the future. Conclusions about the relative effectiveness (for at least maintaining learning levels) of using a certain technological approach, however, should be expected to be stable. That is, if students learn using computer assisted instruction (CAI) delivered by a 1974 minicomputer, then similar results should be obtained using a similar CAI package on a 1985 microcomputer (at much lower cost). Structural barriers such as teacher resistance, on the other hand, can remain in place independent of the other two factors in the absence of appropriate policy. (Structural barriers will be discussed in detail in Part IV.)

Research, in conjunction with technology assessment, tends to support the viability of the widespread use of technology during this decade with respect to the first two factors; effectiveness and technological opportunity. Kulik, Kulik and Cohen (1980), in their meta-analysis of research on computer-based instruction in higher education, found that the teacher time needed at the college level for computer based instruction was 36 percent less than for conventional courses with at least equal degrees of learning and affective response outcomes. A similar analysis is in progress for computer-based instruction at the elementary-secondary level.

Most of the research on the use of computers in elementary-secondary education have focused on the use of the Computer Assisted Instruction (CAI) program developed by Suppes and distributed by Computer Curriculum Corporation. Earlier reviews of the effects of CAI, such as Jamison, Suppes and Wills (1974) and Jamison et al. (1974), concluded that supplementary CAI either improved, or maintained, previous achievement levels when it was used to replace traditional instruction at the secondary level. A more recent review by Thomas (1979) concluded that CAI produces equivalent results to good instruction with respect to achievement, retention and time required to attain mastery at the secondary level.[22]

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[22] The results of an on-going CAI experiment in Los Angeles are presently being analyzed by Educational Testing Service and should be available shortly.

The results of cost analyses are less clear given the lack of methodological standardization.[23] Levin (1980) found that the current $400 per pupil compensatory allocation could fund CAI programs for such students in only two basic skill areas. The CAI packages in that study were leased at high cost, were running on an expensive 1976 computer and were stationed at a central location in the school with extensive environmental and retrofitting costs. The technology examined in that study does not, however, represent the current state of technological opportunity, as the same service can now be obtained using microcomputers for about a third the cost. While this study is an example of the fallacy of extending point in time data to another point in time, the Levin study is valuable in that it developed a standard methodology for doing point in time cost analyses.

Available effectiveness data suggest that even with the present limited state of software development, computers can substitute for teachers in delivering individual, rote learning activities related to basic skills; particularly math. At the same time, high levels of technological opportunity for computer intensive classrooms should appear in this decade. Advances in artificial intelligence provide the potential for more sophisticated versions of educational software; hereafter referred to as intelligent CAI. Such computer packages will perform high level cognitive interactions with students. As an example, Brown (1978) has developed an experimental package that is better than teachers in diagnosing the cause of student errors in math calculations. A number of easy to use programming languages have been developed which facilitate educational interaction with computers; even by preschoolers. Examples include Smalltalk developed by Allan Kay, and LOGO by Seymour Papert.[24] Most of the major education publishing houses are beginning to produce courseware and a wide variety of drill and practice exercises for microcomputers.

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[23] For a critique of cost methodology in technological assessment see Carnoy & Levin (1965).

Several companies are now producing CAI programs for microcomputers. More powerful microcomputers should be available by mid-decade for half the cost of present versions. An inexpensive computer controlled video disk system (around $1200) should also be available by that time.

Table VI describes expected levels of technological

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[24] Smalltalk requires about another half decade of hardware development before it could be used on microcomputers, while LOGO is already available commercially.

TABLE VI

TECHNOLOGICAL OPPORTUNITY FOR LOW-LEVERAGE SYSTEMS FOR PER PUPIL EXPENDITURES OF $50-300

Time Period

	1965-70	1970-1975	1975-1980	1980-1985	1985-1988	1988-2000
Technological Opportunity	Manual programmed instruction	Large central computers in a district, state or county office.	Central mini-computers in a district office or school -- used mainly for CAI and teaching programming to advanced students.	Clusters of microcomputers in a central school location, used mainly for teaching programming to advanced students, drill and practice, and game playing -- microcomputers be-begin to appear in the home.	Classroom clusters of microcomputers used with courseware CAI (some intelligent capabilities), programming for increasing percentages of the school population, classroom management, etc. Central clusters of microcomputer controlled video disk systems. Increasing numbers of microcomputers in the home.	Classroom clusters of microcomputers and intelligent videodisk systems linked to home computers, external data bases and other classroom clusters.

opportunity during this decade. Technological opportunity is defined as the uses of technology that are feasible for expenditure levels of $50-200 per pupil. Such cost levels are considered realistic since they are half of existing compensatory program costs, and are recoverable with small increases in pupil teacher ratios (1-4 students). Table VI suggests that computer rich classrooms, i.e. low-leverage delivery systems, will be feasible by 1985. (See Appendix A for a more detailed cost estimate.) The significance of the mid-decade availability is that the projected feasibility (on an effectiveness and technological opportunity basis) for using low-leverage systems matches the point in time when the demand and need for a technologically relevant curriculum will be growing. As a result, low-leverage delivery systems can be considered as a viable policy option. High-leverage systems, on the other hand, will probably not be feasible on a large scale till later in the decade; or early in the next one.

4. High-leverage efficiency strategies- The advantage of low-leverage efficiency strategies is that they minimize the political dislocations within education that could result from large scale technological substitution. On the other hand, the low-leverage approach is a tradeoff between efficiency and effectiveness concerns; i.e., there is no attempt to maximize potential efficiency gains. High-leverage delivery systems seek to maximize potential cost reductions for the delivery of educational services while

maintaining (at least) existing levels of learning effectiveness. This form of delivery system would seek to use technology to minimize the ratio between the number of people required to deliver educational services relative to the number of people served. There are two basic types of high-leverage strategies that can be envisioned; a) home based, and b) school or community-center based.

Under a futures scenario in which societal poductivity and available fiscal resources continued to decline, and/or teachers refused to cooperate with low-leverage strategies, and/or the needed classroom technological support did not surface sufficiently rapidly, then large segments of society might begin to demand high-leverage technological substitution strategies to reduce cost and taxes. Such delivery systems could also appear spontaneously as increasing numbers of parents began to voluntarily use in-home education technology as an alternative, or supplement, to the cost of private schools.

The prototype of the successful high-leverage system is Sesame Street. Schram (1977) and Jamison, Klees & Wells (1978) have demonstrated the cost effectiveness of high-leverage media such as radio and TV. The major educational limitation of these media, however, is that they do not provide the opportunity for interactive responses. New technologies which will permit simple two-way interaction (i.e., multiple choice responses) are becoming available via satellite and cable telecommunications to both home and school. QUBE is an example of such a system. As computers become more prevalent in the home, more complex interactions will become possible. An alternative to total dependence on telecommunications for high-leverage systems is the distribution of educational courses on videodisks. *As technology evolves, highly leveraged delivery systems will begin to offer the same interactive opportunities as will be available from low-leverage delivery systems* (such a point will, however, probably not be reached until the latter part of this decade).

As an example of the potential of highly leveraged technological delivery systems, Madden (1981) notes:

> Considering productivity in education with respect to videotex, one can compare professors sitting in a room with a hundred or so people against thousands accessing educational routines at their own convenience from their own homes -- augmented in many cases by video programs over TV channels or possibly video cassettes or video disks (p. 260).

The educational establishment has only recently begun to take notice of the potential of cable systems. Education U.S.A. (1980) described the successful use of cable (in a low-leveraged manner) by one school district, and provides useful guidance to school administrators about how to leverage the competition among cable companies to make sure that there is adequate cable capabilities available for education. There has not been, however, any discussion within the establishment of providing highly leveraged educational services via cable. The Walter Annenberg donation to PBS may, however, provide the means and incentive, for such an effort to begin.

The distinction between home and school based delivery systems is not a trivial one from a policy perspective. While the final section of this paper deals with policy issues in detail, it is important to note that home-based high-leverage strategies raise some critical equity issues in terms of access to the services. Access issues are not, however, limited only to home services. The access of school libraries to electronic data bases also presents challenging policy concerns.

5. The implications of composite delivery systems- While distinctions have been made between various forms of delivery systems, it should be noted that they can be intertwined. The basic unit of consideration is not the form of delivery system, but the educational activities themselves; some of which can be delivered via traditional or low-leverage techniques, and others via high leverage techniques. In addition, there is a common component of

each of the new delivery systems, which may constitute a new type of delivery system in and of itself: that of self-delivery. It should be possible by mid-decade for consumers to purchase computers and video disk systems for $500 along with extensive educational software, for either device, for an additional $200. Low cost adapters for cable and satellite reception, as well as interfaces between video disk and computer, will also be widely available around that time. These devices will make it possible to broadcast educational services into the home; either on a regional or world wide basis. As such services become available, increasing numbers of educational institutions may begin to award credit for subjects learned via home technology upon the demonstration of competence.

The availability of composite forms of delivery systems has several structural implications for delivering educational services. First of all, the developing self-service capability will mean that, for the first time, clients will have increasing alternatives to complete dependence on the public schools for the education of their children; even if voucher proposals aren't passed. For example, Papert (1980) has suggested that:

> ...I believe that the computer presence will enable us to so modify the learning

> environment outside the classrooms so that much if not all the knowledge schools try to teach with such pain and expense and such limited success will be learned, as the child learns to talk, painlessly, successfully, and without organized instruction. (p. 9)

Second, the availability of composite delivery systems will mean that for the first time the variety of educational services that a given institution will be able to provide will be largely independent of institutional size. This will be true for small private schools as well as public ones. The political and policy implications of these two factors will be explored in the remaining sections of this paper.

6. Summary- Technology is making new forms of delivery systems feasible during this decade. Given the limitations of traditional forms of delivery systems, it isn't likely that they will be adequate to support the interventionist policy goal of increasing school effectiveness, or the curricular expansion and innovation needed to provide the educational skills required by changing technology. This is particularly true under the condition of constrained resources that is likely to prevail

throughout this decade. Achieving the goals of educational quality during the 80's will, therefore, require a growing dependence on the new forms of delivery systems, the low-leverage form of which will be available by mid-decade. There are, however a number of factors which may impede the use of the alternative delivery systems in public education. The nature of the impediments, as well as the likely consequences of failing to use the new forms of delivery systems, will be explored in the next section.

PART IV - ENVIRONMENTAL COLLAPSE: A THEORY OF THE CONSEQUENCES OF INADEQUATE PUBLIC SCHOOL RESPONSE TO TECHNOLOGICAL NEEDS

If public demands for technology related services increase around mid-decade as predicted, and if the technological opportunity to provide such services also develops around that time, are public schools likely to respond? What are the likely consequences if they do not? This section will explore the answers to these questions.

1. Structural barriers to public school response- Existing literature tends to identify a number of structural barriers that are likely to impede the large scale use of technology in the public schools. The following are the most prominently cited barriers:

a) Inadequate capital resources for schools to purchase computers.
b) No incentives for teachers to use computers.
c) Lack of computer literacy among existing teachers and administrators.
d) Shortages of graduates with technical majors

entering education.

e) Political resistance by teacher unions.

f) Lack of incentives, or profit opportunities, for industry to develop educational software.

g) Inadequate protection against software piracy.

It's difficult to project at this point in time the future impact of each of these factors. The two key limiting factors are probably the availability of software and the ability, as well as willingness, of existing personnel to work with the new forms of technology. With respect to the former factor, there has been a recent rapid increase in the amount of software available; particularly instructional games, math computer assisted instruction (CAI) and a variety of elementary grade curricular material. A lot of new small software companies are emerging, while the large book publishers are hedging their bets by producing software that emulates their books. While the latter software does not represent the state of the art, it has the virtue (from the perspective of the publishers) of requiring minimal investment.

While it is fashionable to point out the high cost of producing software (an often cited figure is $30,000 for an hour of quality instructional material), such statistics are misleading in the context of evolving technology. As low-cost computers, semi-skilled programmers, and program development aids, proliferate, new entrepreneurs can be expected to enter the business of developing educational software; a business for which the capital requirements and development time are declining. The problem is that such software is not likely to contain new, creative, instructional approaches. Most of the software is oriented to drill and practice. Developing more intelligent software which is capable of teaching abstract concepts will require a large R&D investment. The private sector is not, however, likely to make such an investment at the present time due to the piracy problem inherent in existing floppy disk technology. The piracy problem should decline around mid-decade as new, more secure, alternatives for storing programs, such as video disks and high density ROM (Read Only Memory) chips, become available. From that point in time, however, it could take private industry an additional 4 to 5 years to voluntarily produce the more advanced forms of software.

The acceptance of the new technology by teachers, administrators and unions, remains to be seen. There has been a recent spate of grassroots interest in technology among educational professionals. This interest is reflected in the attendance at microcomputer institutes and the rash of new technology journals (five in the last six months) oriented to educators who do not have technical backgrounds.

The motivation for practitioners to engage in such self-learning activities ranges from professional growth to gauging the feasibility of pursuing a career in technology outside of education. Whether this trend of engaging in self-learning activities will continue and attract a significant percentage of existing educators, and whether such training will provide adequate technical skills for the "typical" teacher to manage a "computer rich classroom environment," or whether those who do acquire such skills will remain in education, all remain to be seen. Also uncertain is whether the availability of such learning opportunities will overcome cultural professional biases against change. What is fairly certain is that it will be impossible for education to meet its need for technical people by attracting outsiders to the profession given the overall shortage of such individuals and the uniform salary structure of education. It is also unlikely, in the absence of federal policy initiatives, that the typical college of education will be able to provide substantial amounts of the needed training given their inertial commitment to traditional kinds of programs.

2. Projections of public school response- Given the software and personnel problems, as well as the expected political and cultural opposition to change within the

education profession, most policy studies tend to be highly pessimistic about the widespread adoption of new technology in education. Nilles et al. (1980) estimate that the penetration of microcomputers into the school will only be a sixteenth of the equivalent figure for home use by 1990. A recent survey by the National Center for Education Statistics found only 30,000 microcomputers in the schools for instructional purposes as of Fall 1980. Walling, Thomas & Larson (1979) were also pessimistic about the ability of schools to adopt. They concluded that "...the major impacts...will not be in the school, but probably in the home."(p.4) They also noted that computers would most likely be found in homes where there simultaneously existed a high regard for education and a dissatisfaction with the public schools.

The analyses of the above studies are, however, quite "soft" and may prove to be grossly inaccurate (in either direction). The present willingness of individuals to engage in self-learning activities, as well as the emergence of software development entrepreneurs may possibly mitigate the pessimistic projections of technological adoption by the public schools. Microcomputer companies are tending to report accelerating sales to schools, but those data are also soft.

It appears, therefore, that while pessimistic projections of computer use in the schools predominate, it is really impossible at this point in time to predict the response. What can be predicted with more certainty, however, are the likely consequences if the public school response is inadequate.

3. Political consequences of inadequate public school response- Since access to knowledge about technology will increasingly become a primary work prerequisite, it can be anticipated that there would be strong public dissatisfaction if the public schools failed to provide such training. Traditional conceptions of political process would predict that such dissatisfaction would translate into political activism. Could the public schools use existing political buffers to survive external political activism generated by a failure to become technologically relevant? The preponderance of case studies in the implementation and decision making literature (e.g. Sabatier, 1978) chronicle examples of organizations successfully resisting rational external input, and yet continuing to thrive. Schools, and their unions, score impressively on traditional measures of political power. Traditional theories of political process would probably tend to predict that public schools could resist the pressure to become technologically relevant without having to make substantial changes.

Traditional theories of political process, such as Easton (1965), focus on the efforts of outsiders to modify the internal decision making core of organizations. Pogrow (1981) has, however, hypothesized that the primary forces impinging on education in the 80's will not be external activism, but rather environmental collapse. Environmental collapse is a process wherein dissatisfied constituents do not try to change an organization. Instead, they abandon it for an economically compelling service or product alternative made possible by a fundamentally new technology. Historical examples of politically dominant groups and organizations that became victims of environmental collapse include; scribes, artisans, ocean liners and the pony express. More recent examples are the loss of domestic market dominance by U.S. auto makers, and the failure of the Post Office to obtain its political objective to control electronic mail.

Education is not as likely to be immune from the possibility of environmental collapse in this decade as it was in the past. If technology can reduce the cost of providing a number of educational services, and can expand the number of services offered independent of institutional size, small private schools will be able to offer a comprehensive curriculum at a lower cost differential (relative to public schools) than at present. Tuition tax credits would further narrow this differential. As the cost of private education declines, it becomes a viable option for an increasing number of individuals. Under a conception of environmental collapse, as new technologies for sharing and communicating knowledge become even more economically compelling, new forms of education and educational institutions will develop, and demand for these services will increase; regardless of whether public schools change to a more technologically relevant and efficient form. If public schools do not adjust the nature of the educational services they deliver, and how they deliver them, the utilization of the alternatives by substantial segments of the population will reduce or eliminate the political advantages currently enjoyed by the public schools.

A limited form of environmental collapse may already be occurring in institutions of higher education in the form of what has been termed "academic flight." (Pogrow, 1981) Academic flight refers to a process wherein graduate students and faculty in fields such as engineering and computer science, where technology is progressing rapidly, voluntarily leave academia to work in industry. While industry offers higher salaries, the availability of more modern equipment for engaging in research and learning seems to be an even more critical factor (NSF-DOE, 1981).[25] There appears to be little that universities can do to reverse this trend which, if it continues, will erode the university's ability to attract fiscal resources as the locus of knowledge generation activities shifts away; regardless of how much political power the universities possess. What seems to be happening is that the conversion of industry to information work is modifying some of the historical environmental boundaries and inter-relationships between industry and university; and it is occurring in the fields where knowledge is progressing the most rapidly.

At the other end of the spectrum, elementary-secondary education is losing its market share of basic skills training as industry (Hymowitz, 1981) and the military greatly expand their efforts in that area. While this is presently not a form of environmental collapse, it does suggest a possible mechanism for it. If in the not unlikely event that the new organizations providing basic skills develop a better replicable technology for doing it, then its adoption by private schools could increase their rate of growth; which is a form of environmental collapse.[26]

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[25] Another reason why some students leave earlier than they would otherwise is the often correct perception that they have already learnt what they need to know and what the institution is capable of teaching them. Both Apple, and the largest microcomputer software company, Microsoft, were started by college dropouts.

[26] A new private educational service which is just now starting, is the summer computer camp. If the idea catches on, the next logical step would be to establish private computer schools.

It should be emphasized that environmental collapse is a relatively rare phenomenon in the era of large bureaucracies. The probability of its significantly impacting education in this decade is closely linked to the accuracy of the technology assessment made in Part I. There is probably, however, enough truth in that section to not rely on the simple belief that what was true in the past will be true in the future, or that existing scholarly traditions are adequate to predict the political dynamics that are likely to occur.

4. Alternative conceptions of environmental collapse- Instead of abandoning public schools for private ones, environmental collapse could take another form; the abandonment of schools in favor of high-leverage home-based delivery system. Such an Amish style response is, however, unlikely given the socialization functions of schooling, and the increasing number of single parent and dual wage earner families. The more likely impact of the availability of home-delivered services will be increasing numbers of children obtaining basic skills instruction in the home with parents expecting schools to provide more creative learning and socialization activities. It is not clear whether public schools that had spent half a decade contracting around the provision of basic skills would be able to

respond. At the senior high school levels, the availability of home educational opportunities could result in a reduced willingness on the part of taxpayers to support both four years of high school and comprehensive higher education. This could result in a reduction in the number of years of schooling required for entry into the workplace or higher education; a partial form of environmental collapse.

Regardless of the particular way in which environmental collapse may manifest itself, it is unlikely that public schools will be able to ignore the need to become more technologically relevant without a substantial loss in enrollment.

5. Summary- It has been suggested that if public schools do not increase the scope and technological relevance of the curriculum, the primary political response as of mid-decade will probably be a proliferation of private school alternatives. Technology will make it possible for small private schools to offer a comprehensive curriculum at a relatively low cost. This means that private schools would be a more accessible and desirable alternative than at present. Tuition tax credits would accelerate such a trend. The implications of such a trend for Federal policy are explored in the next section.

PART V - FEDERAL POLICY AND RESEARCH ISSUES

The primary themes to this point have been as follows:

a) There is a need to reorient the curriculum to place more emphasis on providing basic skills necessary to use the new technology, and public demands for such changes will start to manifest themselves around mid-decade.

b) Technological opportunity for alternative forms of delivery systems will become available starting mid-decade.

c) The only way to reorient the curriculum under conditions of constrained resources is to use the new forms of delivery systems to provide a variety of educational services.

d) If public schools fail to adapt and make the curriculum more technologically relevant, the primary mode of public response from mid-decade on will be environmental collapse.

Since the issue of the technological relevancy of schools may have implications for our national defense and economic well being, it is appropriate to consider the implications of the issue for Federal policy. As a result, the purpose of this section is to develop a framework for suggesting an appropriate role for Federal policy, as well as describing the research base needed to support such a conception.

1. Limitations of environmental collapse as a response mechanism- Although the technology relevance of schools is an issue of national concern, if the free market mechanism of environmental collapse can insure adequate alternatives to the public school system, there is no need for Federal intervention. There are, however, three problems with relying solely on environmental collapse to solve the problem of technology relevance. First of all, there is no guarantee that environmental collapse will occur sufficiently rapidly or comprehensively to meet the majority of educational need, or to provide adequate numbers of skilled workers. The second problem is that the generation of large numbers of small private institutions could increase social fragmentation and segregation. The final limitation of a dependence on environmental collapse is that access to training in technology could become a function of wealth. If such training was available only in private schools, or public schools in high wealth areas, the poor would be at a gross disadvantage in the competition for jobs in a changing economy. This could lead to a situation which

Licklider (1979) has referred to as the "electronic ghetto," and could introduce disparities of opportunity that are far more damaging than those addressed by school finance in the 70's.

The existence of the above limitations, however, does not mean that the Federal Government should have the prevention of environmental collapse as its primary policy focus. Aside from the constitutional and philosophical impediments to such a policy goal, the lesson of the past decade is that it's difficult for the Federal Government to stimulate the widespread adoption and implementation of innovation among resistant institutions. As a result, if public schools are not predisposed to reorient their curriculum, environmental collapse is likely to be more effective than Federal policy in providing incentives for the schools to change, or insuring that appropriate alternatives exist if they don't.

A non-interventionist Federal policy perspective that relies on environmental collapse is, therefore, not adequate for dealing with the problem of technological relevance for the reasons already cited. At the same time, Federal policy initiatives that focus on preventing environmental collapse, or that simply continue to focus on the equity issues of the 70's (i.e., improving effectiveness and distributional equity) are inadequate. What does seem appropriate, however, are interventionist policies that retain the basic kernel of existing Federal initiatives, the promotion of equity, but which focus on the equity concerns that are particularistic to an era of changing technology and constrained resources.

2. Technology related equity issues- There are two major equity issues that are likely to result from the impact and potential of changing technology during this decade. The first is Access Equity. Access equity is the distribution of opportunity to acquire the skills necessary to compete for jobs in the 1990 high technology world of work, and the extent to which the distribution is a function of wealth. Access equity can also be extended to include disparities in the distribution of home learning opportunities due to the inability of the poor to purchase home computers or cable hookups.

The second technology equity issue is Efficiency Equity. Efficiency equity is the extent to which the maximum amount of needed educational activities that can potentially be provided within available resources are in fact provided. In other words, if there is a potential for increasing the amount of services provided per unit cost under conditions where an absolute increase in instructional services is likely to improve student learning outcomes and/or opportunity, there is probably some point whereupon the rights of students supersede the potential desire of institutions to maintain the status quo.[27] Whether there are specific legal precedents to support this contention, or to form the basis of a class action suit, is beyond the scope of this paper. If, however, the use of technology is the only way to increase the amount of educational services that can be provided, it does seem appropriate from an equalitarian equity perspective to develop Federal policies that promote the availability and use of such technology.

3. Conceptualizing a role for Federal policy- The common denominator between access equity and efficiency equity is developing the widespread opportunity to utilize technology. The greater the degree of availability, the less likely that any one particular group will control access to it. Technology availability is, however, a function of; a) technological opportunity, i.e. whether existing technology can provide its needed capability, and b) market forces which determine whether such capability will be commercially available. A minimum Federal role would be to intervene where market forces were not providing

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[27] It should be emphasized that the potential improvement would be a by-product of efficiency improvement, increasing the amount and variety of educational activities per unit cost. Simply substituting computer provided activities for equal amounts of teacher provided activities would probably not improve learning.

technology that was both necessary for efficiency equity, but for which technological opportunity existed. In other words, the Federal role can initially be viewed as narrowing the gap between technical opportunity and technological availability.

Widespread availability of technology, however, while minimizing the risk that one group will be unfairly advantaged with regards to access, does not guarantee that it won't happen. This suggests, therefore, a two pronged Federal approach. The first prong could be devoted to eliminating gaps between technological opportunity and availability. Since technological opportunity will exist for large scale use in education by the 1985-87 period, Federal policy should initially focus on removing market impediments prior to that point in time. The second prong of Federal involvement should be a research agenda to measure access equity from just before mid-decade on, and to develop policies to alleviate disparities of wealth related access equity should they appear.

4. The Federal role in eliminating market impediments- While legislative initiatives to date that have proposed a role for Federal involvement in educational technology have focused on providing assistance for the purchase of hardware, there is a sufficiently large market for hardware

outside of education for its cost to continue to decline rapidly. Cutbacks in the funding of NASA, the Federal agency whose initial support enabled the then fledgling semiconductor industry to develop, will be offset by increases in defense spending for technological advancement. As a result, it can be expected that the market availability for hardware will match technological opportunity, and will therefore not require any additional policy intervention.

The major market impediment to technological availability involves the development of intelligent instructional software; particularly for language arts. As already noted, the market is likely to provide the necessary software for basic drill and practice. It is not likely, however, that the market will invest the sums needed to produce the software necessary to support more advanced types of cognitive development before mid-decade. Such software could probably be developed for a relatively modest commitment of $15-25 million/year for five years.

In addition to providing specific funds for intelligent instructional software development, there is a need to integrate previous, as well as current, research in education and other disciplines that is relevant to such a development effort. For example, Wilson (1981) notes that few of the results from NIE research on reading have been incorporated into existing language arts software. At the same time, while a number of agencies are funding research on artificial intelligence which has implications for the design of instructional software, there has been little formal linkage between these disciplines.

An alternative, but less satisfactory, approach to a software development project would be Federal categorical grants to local districts to specifically purchase software. However, unless vendors were convinced of the long term nature of the funding, and of market expansion, it is unlikely that they would commit the necessary R&D funds to develop advanced forms of software. It would be far easier for the vendors to concentrate on marketing their existing products.

Providing grants to school districts to purchase hardware will do little to stimulate the development of advanced forms of software.[28] Administrators presently tend to be relatively unsophisticated in making decisions about what kinds of software to purchase for their hardware. Software tends to be an afterthought--an attitude not likely to induce major investments by publishers.

If the policies suggested at the beginning of this section were implemented, it should be possible to have a variety of intelligent software available in about five years to interface with a new generation of cost-effective microcomputers. This would insure wide availability of intelligent instructional technology at that point in time when public demand, and the economic necessity, for such technology is expected to be increasing rapidly. In addition, the availability of such software would increase the efficiency potential of low-leverage systems while also increasing the probability of achieving effectiveness gains along with the efficiency benefits.

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[28] An alternative to providing grants for hardware would be to loosen restrictions on using existing Federal funds to purchase computers. In addition, if the Federal government did provide some hardware support, it might be more important to fund the purchase of hard disk networks rather than the computers themselves. This would give interested districts the ability to store more sophisticated programs while sharply reducing the cost of each computer subsequently purchased.

5. Measuring access equity - A Federal policy to promote the widespread availability of intelligent instructional technology by around mid-decade reduces, but does not eliminate, the possibility that systematic disparities in access to learning about, and using, technology will develop. Between these two components of access equity, "access to learning about" is the easier of the two to measure. It is easy to develop a set of recommended curricular activities that are necessary for adequate learning about technology. (e.g., Courses in COBOL programming and word processing at the high school level, and courses in BASIC programming and computer literacy at the elementary and junior high levels.) It is also relatively easy to measure which students have the opportunity to engage in such learning activity in terms of whether the courses are offered. What is more difficult to measure is whether students are being provided sufficient opportunity to use computers, not just for the purpose of

learning how to use technology, but for also obtaining sufficient instruction in basic skills and other subjects under the alternative delivery systems described in Part III. How much computer use is appropriate? Technology advocates routinely suggest giving everyone a computer. Is such an expense justifiable?

While it is possible to compare how many computers School A has as compared to School B, such a gross input measurement approach repeats the past mistakes of equity policy research in the 70's. Much of the equity policy research of the 70's focused on measuring the distribution of fiscal input resources and examining the production function between inputs and educational outcomes. It is the latter research which is of primary interest to this discussion.

The production function work of the previous decade was largely unsuccessful in establishing important and systematic relationships between inputs and learning effectiveness. There were, however, methodological problems with the research. The primary problem with the studies was that the variables tended to represent school or distict characteristics (i.e., number of books in the library), and performance data tended to be aggregated at the school or district level. In retrospect, such analysis made no sense since the locus of learning production was the classroom and aggregating those dynamics into school and district level statistics was bound to introduce confounding effects.

The work of Sommers & Wolfe (1976) was significant in that they used the classoom as the unit of analysis. They also found a number of significant policy relationships between input variables such as teacher characteristics, student ability, class size, time in classroom, and student achievement. As important as this study was, however, it did not link classroom instructional strategy, and the resultant classroom activities, to achievement. One more disaggregative step was needed in production function analysis.

The methodological issues associated with linking the characteristics of the instructional activities to which students are exposed and their learning achievement was outlined in a recent series of papers (Dreeben & Thomas, 1980). The contributions of Harnischfeger & Wiley (1980) and Brown & Saks (1980) to this volume described the feasibility and utility of this type of analysis, hereafter referred to as micro-production function analysis, while Berliner (1980) developed a framework for characterizing classroom activities. Of particular importance are Berliner's findings that time on task on instructional activities is a major contributor to student achievement, and that large variances exist across classrooms in the amount of time that students spend on given educational activities. Berliner attributes the variance to the managerial skills of teachers. In other work Berliner developed the concept of teacher as executive.

The micro-production function research provides a framework for defining the goals of a low-leverage delivery system, as well as for defining more precisely what constitutes appropriate degrees and types of technology use. Specifically, for a low-leverage delivery system to have the potential for increasing effectiveness, as well as for reducing costs, it must do the following:

a) It must simplify the managerial aspects of teaching by reducing the amount of time teachers spend on; 1) general administrative tasks, and 2) managing each classroom instructional activity.

b) It must increase the net amount of instructional activities provided to each student in classrooms, both in terms of variety and time available for students to work on each one.

The first requirement implies that teachers have classroom computers which can keep track of classroom logistics such as student progress and attendance, and which has a limited diagnostic capability. The second condition implies the classroom availability of phsically implemented instructional systems that enable, and motivate, students to engage in self-service learning activities. Table VII summarizes the differences between the traditional form of delivery system and the technology based ones with respect to the above requirements.

The above requirements provide a basis for designing a model of classroom process which can simultaneously provide the basis for empirical research on the effects of computers in classrooms, as well as for defining equity access in terms of what constitutes appropriate amounts and kinds of computer use. The following model is therefore proposed for conceptualizing the design of a low-leverage delivery system:

- There are a series of educational activities that occur in classrooms which are related to a series of learning outcomes.[29]

- Each activity has a series of definable characteristics which are related to a particular learning outcome; e.g., time engaged in, degree of

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[29] These activities should include socialization functions as well as those directly related to cognitive development.

TABLE VII

A COMPARISON OF THE RESEARCH IMPLICATIONS OF THE ALTERNATIVE FORMS OF DELIVERY SYSTEMS

	TRADITIONAL	LOW LEVERAGE	HIGH LEVERAGE
Fundamental Educational Unit	School or classroom	Educational activities in classrooms	Courses
School Finance Emphasis	Expenditure and tax equity	Efficiency equity and access equity	Maximizing efficiency through technological substitution
Research Base	Macro production functions, learning theory, diffusion of innovation, knowledge utilization, interest group theory	Micro level production functions, learning theory, artificial intelligence, cost-effectiveness analysis, politics and sociology of automation	Cost-effectiveness analysis, politics and sociology of automation

individualization, mode of presentation, etc.

- Each activity characteristic has a function which relates it to teacher time and cost.

- Each activity has a technology substitution potential ranging from 0 to 1. This factor reflects the extent to which technology can be used to provide the activity characteristics consistent with the results of effectiveness research and technological opportunity at a given point in time.

- There is a definable cost function for substituting technology for particular activities for different states of technological opportunity.[30]

- Constraints to the model include; 1) total time available to teachers in a school day, and 2) total funds available per student.

To the extent that micro-production function analysis could link classroom activities to learning, and to the extent that alternative approaches to providing classroom activities could be linked to learning outcomes, then the above model could be used to determine analytically whether there is an optimal level of technological substitution for maximizing effectiveness. If it was not possible to completely specify the first matrix, analysis could still be performed to determine the optimal level of technological substitution for maximizing the amount of time students engage in a predefined set of activities. Such analysis would provide a basis for defining in a more rigorous fashion how much computer access should be considered appropriate for the purposes of defining equity access and developing policy initiatives.

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[30] The model would have to provide for the possibility that the presence of the technology could alter the learning outcome matrix for equal amounts of activities.

The above model is of course an ambitious one. Its feasibility depends on continued basic research in production function theory, classroom management strategies, teacher incentives and learning theory. The model does, however, suggest a way in which a multidisciplinary basic research agenda can be linked towards a common policy objective.

6. Future policy and research issues- This section has suggested that Federal policy should focus in the near term on funding a program to develop a variety of intelligent instructional software packages and thereby

increase the availability of the technology shortly after mid-decade. It has also been suggested that there is a need to monitor the developing patterns of computer use in the schools (public as well as private) to determine whether disparities in access and efficiency equity are developing.

If it develops that the proposed strategy of maximizing availability does not prevent disparities from developing, additional targeted Federal policies might be needed. As an example, equalizing access to home-based delivery systems might necessitate requiring TV manufacturers to include microcomputer chips in their sets; much as the government presently requires a UHF receiver. Another possibility would be to provide tax credits to businesses which train the poor in the use of technology, or provide incentives for schools (public as well as private) with technologically relevant curricula to recruit students from poor families in a modified form of voucher scheme.

There is also a need to leverage scarce Federal research dollars. Such leveraging would require integrating whatever additional specific funding could be obtained for technology specific activities, with existing R&D activities in education and other disciplines. As already noted, there is much research in other disciplines and agencies, such as the Department of Defense, that would be relevant to developing more intelligent forms of software.

There is also the need to integrate research on the dynamics of introducing microcomputer technology into social systems, with general research and theory formation in the social science disciplines. Such integration would be of benefit to both social scientists and technologists. For example, technologists contemplating the design of a low-leverage delivery system could benefit from examining research on classroom sociology, learning theory and micro production function research. Social scientists would benefit by having an opportunity to study how social system response to this new widespread phenomenon corresponds to what would have been predicted by existing social science theory. Where incongruities appear, they would be valuable for generating and testing new theories which would be relevant to a broad range of phenomena; past as well as present. One specific example of the need for a theoretical shift in political science theory that has been speculated about in this paper is the need to substitute conceptions of environmental collapse for those of interest group dynamics. If that is true, it then becomes more important to empirically describe the relationship between environmental change and the shift away from interest group politics, as opposed to continuing to try to generate new theory on traditional questions about interest group politics. Such a shift in research emphasis would have enormous implications for open systems theory and innovation theory, as well as for political science.

The introduction of microcomputers into the classroom also has theoretical implications for a wide variety of other disciplines. For example, economists would probably be very interested in the micro production function research outlined in the previous section. In addition, the potential ability of technology to eliminate organizational size as a primary determinant of the scope of the curriculum that a given school can provide has implications for the design of school funding formulas and governance mechanisms.

The importance of, and potential payoffs from, integrating technology related R&D with traditional research concerns is such that it may be necessary to formalize that priority somewhere within the Federal educational establishment. While specific details of how to institutionalize such a function is beyond the scope of this paper, such a technology ombudsman function would have to; a) have a rather broad mandate, b) be placed high up in the hierarchy, and c) be run by someone who has credibility with both technologists and social scientists.

Finally, the ideas in this paper have major implications for speculating about changes in the nature of the governance process and the way in which educational professionals are trained and motivated. If low-leverage systems are to be used extensively, traditional conceptions of who manages the instructional process will have to be changed. District management, or even school-based management conceptions will be inadequate. Rather, the fundamental locus of instructional management will have to shift to the classroom; with teacher as manager as well as teacher. Whether such changes will be feasible and/or politically acceptable within the public school system remain to be seen. It may be that large numbers of teachers, if given the option of having class size maintained and taking a salary cut, or having class size increased without technological support, or having it increased with such support, will voluntarily opt for the latter choice. While conventional wisdom would therefore predict union intransigence on the issue of technological substitution, such may not be the case; particularly if benefits from using technology can be clearly demonstrated for both students and teachers.

VI- SUMMARY

Those who attempted to project the course of education in the 70's by extrapolating the trends of the late 60's and early 70's were very wrong. According to such projections the 70's should have been a time of increasing student radicalism and one of unsurpassed innovation in education. Conventional wisdom was once again proved wrong as the trends underwent dramatic change once the decade got under way.

The primary trends that are in evidence at this time are growing conservatism and a push for basics. It would be easy to conclude that these trends will continue to be the dominant ones for the remainder of this decade. The methodology employed in this monograph, however, suggests that such a conclusion would be a misleading one for policy makers. Instead, what appears more likely to occur is that the now dominant trends will be displaced, or modified, around mid-decade by new needs (and heightened consciousness of these needs) resulting from widespread adoption of microcomputer technology in the home and workplace. The change in trends will probably not be a gradual process but one which will occur suddenly around mid-decade and intensify thereafter in geometric fashion.

Given the observable trends at this point in time, it is not likely that significant numbers of school districts will make massive commitments to computer use. Rather, a few districts are making large scale commitments out of a desire to be viewed as a lighthouse district in this area, while some are reacting in the opposite way by banning computers from the schools. The vast majority of districts are taking small initial steps, and are experimenting with the use of computers on a small scale. Such an approach is probably a prudent one at the present time given existing levels of expertise and technological opportunity. The policy question, however, is whether there will be a sufficient accumulation of expertise and commitment over the next several years to enable schools to quickly accelerate their use of technology and develop more technologically relevant curricula.

Federal policy that assumes that existing trends will continue, and which as a result, either focuses primarily on improving basic skills, or withdraws from any type of specific commitment, is likely to fall short of meeting the needs of this country if, as predicted, educational demands shift and structural barriers appear; barriers which enlightened policy initiated at the present time could avoid. Specifically, a minimum Federal program has been recommended which supports the development of intelligent software with financial support (estimated at a total of $125 million spread over five years) and a vehicle for integrating this new effort with other related Federal activities and research. Initiating such a policy at the present time will reduce the probability that disparities in efficiency and access equity will develop in the future. Such policy will also increase the probability that the educational system will be able to provide the skills needed to maintain our economic leadership in an increasingly competitive world, while at the same time increasing educational opportunity for students.

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APPENDIX A

COST ESTIMATE FOR A COMPUTER RICH CLASSROOM IN 1985

The following is an estimate of the cost over five years of placing ten microcomputers (The equivalent of an Apple) in a classroom networked with a hard disk system and printer. No environmental conditioning or reconstruction is expected to be needed, and the electrical consumption of such equipment should be very small.

10 microcomputers	$600 @	$6,000
Hard disk system (10 MB)		2,500
Dot matrix printer		600
Software		2,000
Supplies	$1,000/yr.	5,000
Installation (Labor + cables)		500
Service	$300/yr.	1,500
Miscellaneous	$300/yr	1,500

Total cost $19,600

Assume 30 students per class, five year life expectancy for the equipment with no salvage value.

Cost per student per year $131

Assume that the direct cost of instruction in 1985 for that class under a traditional delivery system is $27,000 for a full-time teacher and $8,000 for a part time aid. The added cost of the equipment could be recouped by increasing the pupil teacher ratio by about 3.5 students. Over time, as the cost of the technology continued to decline and salaries increase, savings would be realized from a pupil teacher ratio increase of 3.5 students. To the extent that the availability of the technology would make it possible to increase the pupil teacher ratio beyond that point, additional savings would be realized.